OHIO RIVER POLLUTION SURVEY

FINAL REPORT
TO THE
OHIO RIVER COMMITTEE

SUPPLEMENT "D"

INDUSTRIAL WASTE GUIDES

1798

FEDERAL SECURITY AGENCY
U. S. PUBLIC HEALTH SERVICE
CINCINNATI, OHIO
1942

UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN
PRAIRIE RESEARCH
INSTITUTE

Digitized by the Internet Archive
in 2013

http://archive.org/details/ohioriverpollu0unit

INDUSTRIAL WASTE GUIDES

Supplement "D" to
Final Report to the Ohio River Committee
Ohio River Pollution Survey

1798

FEDERAL SECURITY AGENCY
U. S. PUBLIC HEALTH SERVICE
OFFICE OF STREAM SANITATION
CINCINNATI, OHIO
1942

INDUSTRIAL WASTE GUIDES

Contents

Page

Survey Authorization 1
Description of Guides 1
Uses of Guides 2
Sources of Information 3
Survey Methods 4
Sewered Population Equivalents 5
Remedial Measures 7
Survey Results 8
Acknowledgments 10
Personnel 10

List of Tables

1 Summery of Waste Discharges, Sewered Population Equivalents and Employees per Unit of Production, with Typical Analytical Results for Various Industrial Wastes 6
2 Ohio River Basin - Summary Showing Industrial Wastes Not Discharging to Municipal Treatment Plants, Suggested Industrial Waste Discharges to Municipal Treatment Plants and Total of Entire Industrial Waste Load in the Basin 9

List of Figures

1 Map - Ohio River Basin - Suggested Industrial Waste Correction. . . . . (Facing) 8

Appendices

Industrial Waste Guides

I Brewery B-1
II Cannery Cn-1
III Coal Washery Cw-1
IV Coke Ck-1
V Cotton Ct-1
VI Distillery D-1
VII Meat Mt-1
VIII Milk Mk-1
IX Oil O-1
X Paper P-1
XI Tannery T-1

Survey Authorization

The Ohio River Pollution Survey, recently completed, was authorized by the Congress to cover the Ohio River and its tributaries, with the specific instructions:

(1) "... to ascertain what pollutive substances are being deposited ..." and

(2) to make the survey "... with a view of determining the most feasible method of correcting and eliminating the pollution ..."

In considering industrial wastes, these instructions have required, first, a determination or estimate of the strength and quantity of each industrial discharge and, second, a determination of indicated treatment or other corrective measures with estimate of cost to apply to each of these discharges. With a total of 1,800 waste-producing industrial plants in the basin, the assignment has been a work of considerable magnitude.

Description of Guides

An essential step in the work has been the preparation of the Industrial Waste Guides, which summarize information available on pollution problems connected with the various classes of industrial establishments found in the Ohio River Basin. Characteristic features of the guides, which are all prepared along similar lines, include:

(1) An "Abstract" giving, in brief form, the essential features of the guide.

(2) "Description of Process" covering the various principal operations in the industry.

(3) "Raw Materials and Products" enumerating these items and giving quantity relationships including number of employees.

(4) "Sources and Quantities of Wastes" discussing waste-producing operations and estimating quantities from individual processes and the total industry.

(5) "Character of Wastes" presenting analytical results of individual process wastes and the total composite wastes, and discussing important characteristics of each waste.

(6) "Pollution Effects" discussing principal objections to discharge of each waste to streams.

(7) "Remedial Measures" discussing corrective measures involving steps within the plant such as recovery practice and disposal of waste materials other than to the sewer, as well as treatment practiced or in various stages of development. Cost data, when reliable, are included in some cases.

(8) "Bibliography."

(9) "Note-Taking Form" as used in the field in collecting data from industrial plants.

(10) "Inspection Report" such as is prepared by the field engineer from the data on the note-taking form and other notes.

(11) "Flow Diagrams" illustrating in diagrammatic form the industrial process steps, waste flows and recovery practices.

The eleven industrial waste guides presented, cover the principal types of industries found in the Ohio River Basin. Steel mills which contribute acid pickle liquors, certain chemical plants which contribute acid and organic materials, plastic and synthetic fiber manufacturing plants and textile plants other than cotton, are notable exceptions. Information has been collected on the wastes from these classes of industry but wide variations which make each plant unique, or time limitations, have prevented presentation of this information in the form of guides. Other industries generally mentioned in industrial waste discussions are not common to the Ohio River Basin.

Uses of Guides

The Industrial Waste Guides have been of great assistance in the industrial waste activities of the Ohio River Pollution Survey, both along lines originally intended and along lines that later developed during the course of the work. Some of the more important uses are as follows:

(1) Assistance to field engineers.

(2) Assistance in estimating strength, volume and sewered population equivalents of industrial discharges.

(3) Assistance in determining indicated remedial measures and costs.

(4) Assistance in soliciting unpublished information from engineers, chemists and others familiar with specific industrial wastes.

Sources of Information

Basic information on industrial wastes, including remedial measures, has been obtained from: (1) the published literature, (2) private communications with engineers and chemists, municipal and private, equipment manufacturers, industrial management, trade associations and others, (3) sampling and gaging results obtained in connection with the present survey, (4) field engineers' reports on routine inspections in connection with the present survey, and (5) U. S. Public Health Service files.

The review of published information has been largely confined to American publications, and European and other foreign practices are incorporated, with few exceptions, only in so far as it is reported in American literature. Important references are listed in the bibliographies of the individual guides.

Excellent co-operation and valuable information have been received through private communications from municipal and private engineers and chemists, equipment manufacturers, industrial management, trade associations and others. This information has been received as a result of written inquiry and consultation. The industrial waste guides were first issued in limited number in preliminary form and distributed to those familiar with specific industries. Comments, corrections and supplementary information received in reply have been particularly valuable. Results of sampling and gaging studies made by the Sanitary District of Chicago are worthy of special mention.

Detailed information on representative industrial plants has been secured during the present survey by co-operative arrangements with the Tennessee Valley Authority, the State of West Virginia, and the cities of Louisville, Kentucky, and Cincinnati, Ohio. Programs were co-ordinated and assistance was furnished in the cases of the Tennessee Valley Authority, the State of West Virginia and the City of Louisville. Sampling and gaging studies were made at a total of 29 industries, of which 15 were in the Tennessee Valley, 3 in the State of West Virginia, and 11 in and near the City of Louisville. Particular attention was devoted to securing information on individual discharges rather than confining activities to the total plant wastes. In the cases of Louisville and Cincinnati, rather extensive surveys were made by these cities for the purpose of designing sewage collection and treatment works for the abatement of pollution. In the case of Cincinnati, individual industries were not as a rule studied, but comprehensive sampling and gaging studies were made on all sewer outfalls, making it unnecessary for the Ohio River Pollution Survey to cover the industries individually.

Some of the best available sources of information on remedial measures now in practice are the reports of routine inspections made in connection with the Ohio River Pollution Survey. As shown on Table 2, slightly over half the industrial plants not now discharging to municipal treatment plants have already taken at least minor corrective measures to abate pollution. The detailed data has been of considerable assistance in determining indicated remedial measures, as many of the outstanding instances of industrial waste treatment are located in the Ohio River Basin.

As a result of the previous Ohio River Survey and of other studies, the Cincinnati files of the U. S. Public Health Service contain additional information on industrial wastes, particularly on the subject of strength and quantity factors.

Survey Methods

The standard procedure followed in the survey of industrial waste discharges has been by inspection and report, using a classified industry (I-1 to I-12) or the miscellaneous (I-M) "note-taking form" and the standard form of report shown at the back of each Industrial Waste Guide.

At plants that are unique, or which, by reason of products or processes could not be compared with others, it was necessary to collect samples for examination and to measure or estimate flows. Samples of individual discharges were collected at the point of creation of the waste in a number of instances. Accurate information is usually available on quantities of such discharges which are often intermittent, whereas sampling of total plant discharges diluted by cooling and other waters would necessitate careful, long-time gaging and composite sampling.

Sampling and gaging studies over periods of from two to ten days were carried out at a number of typical as well as unique industries. Special effort was made to select industries willing to furnish detailed operating data covering the period of study, so that gaging and analytical results could be correlated with plant operations.

Sewered Population Equivalents

Industrial wastes may be objectionable for a great variety of reasons. They may contain:

(1) High organic or biochemical oxygen demand content.
(2) Suspended solids.
(3) Chemicals toxic to aquatic life.
(4) Excess acid, hardness or salinity
(5) Taste and odor producing substances.
(6) Undesirable coloring matter.

Although no single measure of pollution is applicable to all of these types of industrial wastes, the biochemical oxygen demand is the most nearly satisfactory. Sewered population equivalents of industrial wastes have been based on 0.167 pounds of 5-day, 20° C. biochemical oxygen demand per capita per day.

In a few cases, sewered population equivalents based on suspended solids have been considered. Such an equivalent is of interest at industrial plants discharging or planned for discharge to municipal treatment plants, particularly of the plain sedimentation type where sludge quantities are important. Per capita contribution of suspended solids has been taken as 0.2 pounds per day.

A summary of the typical sewered population equivalent (B.O.D.) figures based on units of production is shown on Table 1.

Table 1 - Summary of Waste Discharges, Sewered Population Equivalents, and Employees per Unit of Production, with Typical Analytical Results, for Various Industrial Wastes.

Industry	Unit of Daily Production	Employees per Unit	Wastes Gal. per Unit	Typical Analyses p.p.m.		Sewered Population Equivalents (1)		Remarks
				B.O.D.	Susp.Sol.	B.O.D.	Susp.Sol.	
rewing	1 barrel of beer	0.25	470	1,200	650	19	9	Spent grain dewatered.
do	do	0.25	470	800	450	12	6	" " sold wet.
anning								
Apricots	100 cases #2 cans	-	8,000	1,020	-	410	-	
Asparagus	do	-	7,000	100	30	35	9	
Beans, green	do	-	3,500	200	60	35	9	
" , lima	do	-	25,000	190	420	240	440	
" , pork and	do	-	3,500	920	225	160	33	
Beets	do	-	3,700	2,600	1,530	480	240	
Corn, cream style	do	45	2,500	620	300	75	30	
" , whole kernel	do	-	2,500	2,000	1,250	250	130	
Grapefruit, juice	do	-	500	310*	170*	8*	3*	* Excl. peel bin wastes.
" , sections	do	-	5,600	1,850	270	520	63	
Peaches-Pears	100 cases cans	-	6,500	1,340	-	440	-	Size of can unknown.
Peas	100 cases #2 cans	1	2,500	1,700	400	210	40	
Pumpkin (Squash)	100 cases #2½ cans	-	2,500	6,400	1,850	800	190	
Saurkraut	100 cases #2 cans	-	300	6,300	630	100	8	
Spinach	do	-	16,000	620	-	490	-	
Succotash	do	-	12,500	520	250	330	130	
Tomatoes, products	do	-	7,000	1,000	500	350	150	
" , whole	do	6.5	750	4,000	2,000	150	60	
oal Washery	1,000 tons coal washed	6	-	15	115,000	-	-	
oke	100 tons of coal carbonized	8	360,000	85	-	1,500	-	Wastes cause tastes and odors.
istilling, grain								
Combined wastes	1,000 bu.grain mashed	40	600,000	230	360	3,500	2,300	Excl.intentionally disch.slop.
Thin slop	do	-	-	34,000	-	55,000	-	
Tailings	do	-	-	740	-	50	-	
Evaporator condensate	do	-	-	1,200	-	1,500	-	
istilling, molasses	1,000 gal. 100 proof	8	8,400	33,000	3,270	12,000	1,000	Molasses slop.
Cooling water	do	-	120,000	-	-	-	-	
eat								
Packing House	100 hog units of kill	30	550	-	-	77*	25*	*Paunch manure to sewer.
do	do	30	550	900	650	24	14	(1 cattle equals 2½ hog units=)
Slaughterhouse	do	20	150	2,200	930	13	6	(2½ calves = 2½ sheep)
Stockyards	1 acre.	-	25,000	65	175	80	180	
Poultry	1,000 lbs. live weight	6	2,200	-	-	300	160	Av. wt. = 4.5 lbs./animal.
ilk								
Receiving Station	1,000 lbs.raw milk & cream	0.15	180	500	-	4	2	
Bottling Works	do	0.89	250	-	-	6	3	
Cheese Factory	do	0.38	200	100	750	16	9	
Creamery	do	0.16	110	1,250	660	6	3	
Condensery	do	0.47	150*	1,300	750	7	4	* Excl. vacuum pan water.
Dry Milk	do	0.39	150	480	-	6	3	
General Dairy	do	1.09	340	570	540	10	5	
il Field	100 bbls. crude oil.	1.3	18,000	-	-	-	-	
il Refining	do	3	77,000	20	50	60	120	1 bbl. = 42 gal.
aper								
Paper Mill	1 ton of paper.	4.4	39,000	19	452	26	520	No bleaching.
" "	do	4.6	47,000	24	156	40	220	With bleaching.
Pasteboard	do	2.1	14,000	121	660	97	445	
Strawboard	do	1.4	26,000	965	1,790	1,230	1,920	
Deinking	do	-	83,000	300	-	1,250	-	Old paper stock.
aper pulp								
Groundwood	1 ton dry pulp	2.5	5,000	645	-	16	-	
Soda	do	3.0	85,000	110	1,720	460	6,100	
Sulfate (Kraft)	do	-	64,000	123	-	390	-	
Sulfite	do	3.1	60,000	443	-	1,330	-	
anning, vegetable	100# raw hides	7	800	1,200	2,400	48	80	
" , chrome	do	-	-	-	-	24	40	
extile								
Cotton								
Sizing	1,000# goods processed	-	60	820	-	2	-	
Desizing	do	-	1,100	1,750	-	96	-	
Kiering	do	-	1,700	1,240	-	108	-	
Bleaching	do	-	1,200	300	-	17	-	
Souring	do	-	3,400	72	-	12	-	
Mercerizing	do	-	30,000	55	-	83	-	
Dyeing								
Basic	do	-	18,000	100	-	100	-	
Direct	do	-	6,400	220	-	71	-	
Vat	do	-	19,000	140	-	130	-	
Sulfur	do	-	5,400	1,300	-	360	-	
Developed	do	-	14,400	170	-	120	-	
Naphthol	do	-	4,800	250	-	59	-	
Aniline Black	do	-	15,600	55	-	41	-	
Print Works	do	-	4,500	95	-	15	-	
Finishing	do	-	6	1,250	-	0.4	-	
Rayon Manufacture	1 cord wood distilled	35	680,000	30	-	1,000	-	Wood distillation process.
" "	1,000# rayon produced	64	160	4.4	19	35	130	Cupra-ammonia process.
" "	do	50	140	110	96	800	580	Viscose process.
" Hosiery	1,000# hose produced	-	9,000	330	-	150	-	Boil-off and dye wastes.
Silk Hosiery	do	-	13,700	1,720	-	1,180	-	Boil-off,dye, & finish wastes.
Woolen Mill	1,000# finished goods	-	70,000	114	-	400	-	Scouring & dyeing-no grease wool.
" "	do	-	240,000	125	-	1,500	-	" " " -100% " "

(1) Persons per unit of daily production.

Remedial Measures

Reduction of industrial waste pollution is generally accomplished by one or more of the following measures:

(1) Changes within the plant itself. This may involve re-use of all or part of the waste within the plant, development of by-products, changes in plant processes, or merely greater care in plant operation to reduce the amount of material discharged as waste.

(2) Treatment with municipal sewage. Many industrial wastes can be quite effectively treated in this way. It is often necessary to pretreat the waste at the source or to segregate certain portions of the wastes within the plant and exclude those from the municipal sewers to prevent damage to sewerage structures or sewage treatment processes.

(3) Treatment in a special industrial waste treatment plant. For many types of wastes, such plants employ essentially the same processes as sewage treatment plants. Other types of waste require specially developed processes. Most of the plants use the principle of sedimentation for removal of settleable solids.

The first method is usually the most economical and is one of those generally applied. It is occasionally possible to completely eliminate pollution and to recover valuable by-products, but this is not the usual situation. Ordinarily some pollution remains and some expense is involved. The second method is simplest from the standpoint of the industry. It is also the most satisfactory from the standpoint of administration of pollution abatement programs, and it reduces the number of possible sources of pollution and concentrates responsibility for effective waste treatment. It is usually necessary to make special provisions in the design of a municipal sewage treatment plant if an appreciable amount of industrial waste is to be treated. Subsequent changes in the industrial waste load sometimes cause difficulties.

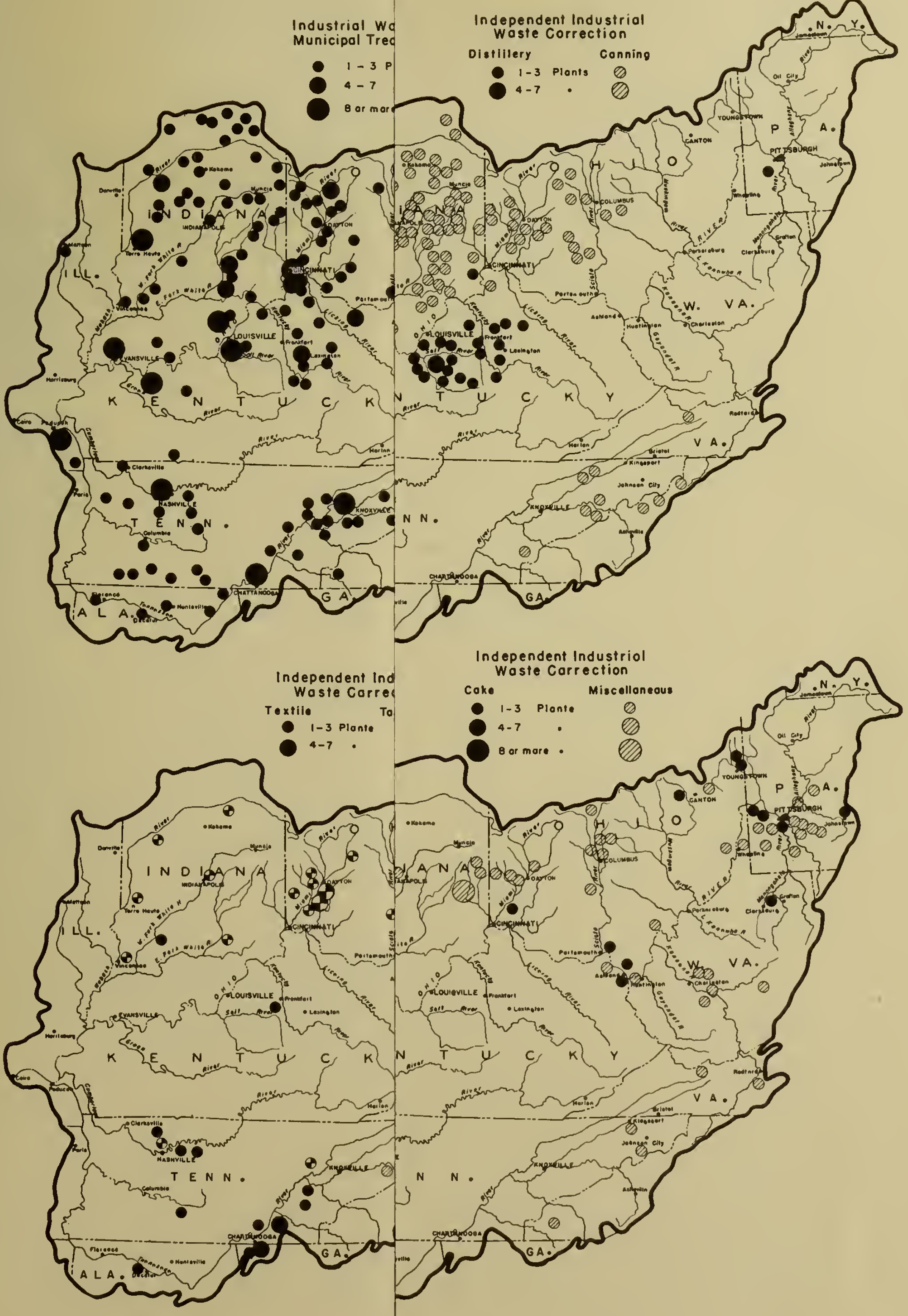
The third method, treatment in a special industrial waste treatment plant, is used when the first is insufficient and the second impracticable. Segregation of cooling and other inoffensive waters for separate disposal is almost universal practice in attacking industrial waste pollution problems. Likewise, separate collection of highly offensive concentrated materials or wastes for special attention, utilization or recovery, will often accomplish reduction in pollution at great savings over treatment costs.

In the industrial waste treatment field, chemical precipitation is popular, due largely to its ability to operate unaffected by greatly varying loads and toxic materials and to its lesser capital cost in comparison to biological processes. In those cases where removal of settleable solids is sufficient, the problem is not difficult, but satisfactory methods for the relatively complete removal of B.O.D. are available for only a few of the more common types of wastes, such as those from breweries, meat plants, milk plants and some types of canneries and distilleries. There is a pressing need for the development of more efficient and economical methods for relatively complete treatment of other types of wastes. These problems are discussed in more detail in the individual Industrial Waste Guides.

Survey Results

The results of industrial waste activities are presented in the individual tributary basin summaries of the Final Report of the Ohio River Pollution Survey. The magnitude of the problem of organic industrial waste is reflected in the sewered population equivalent figures. Wastes objectionable because of acid, salts, taste-producing or other characteristics are covered in discussion. Table 2 of this supplement is a repetition of Table 3 of the report proper, and summarizes data on the industrial waste pollution load of nearly 10,000,000 sewered population equivalent found in the Ohio River Basin.

Figure 1 is a repetition of Figure 12 of the report proper and shows the location of plants by industries where corrective measures are indicated. Inasmuch as the wastes from many industrial plants are now handled in a satisfactory manner, the figure does not show all plants but it indicates the areas in which industries of specific types are found.



NOTE:- Exclusive of plants where
present corrective measures
are adequate

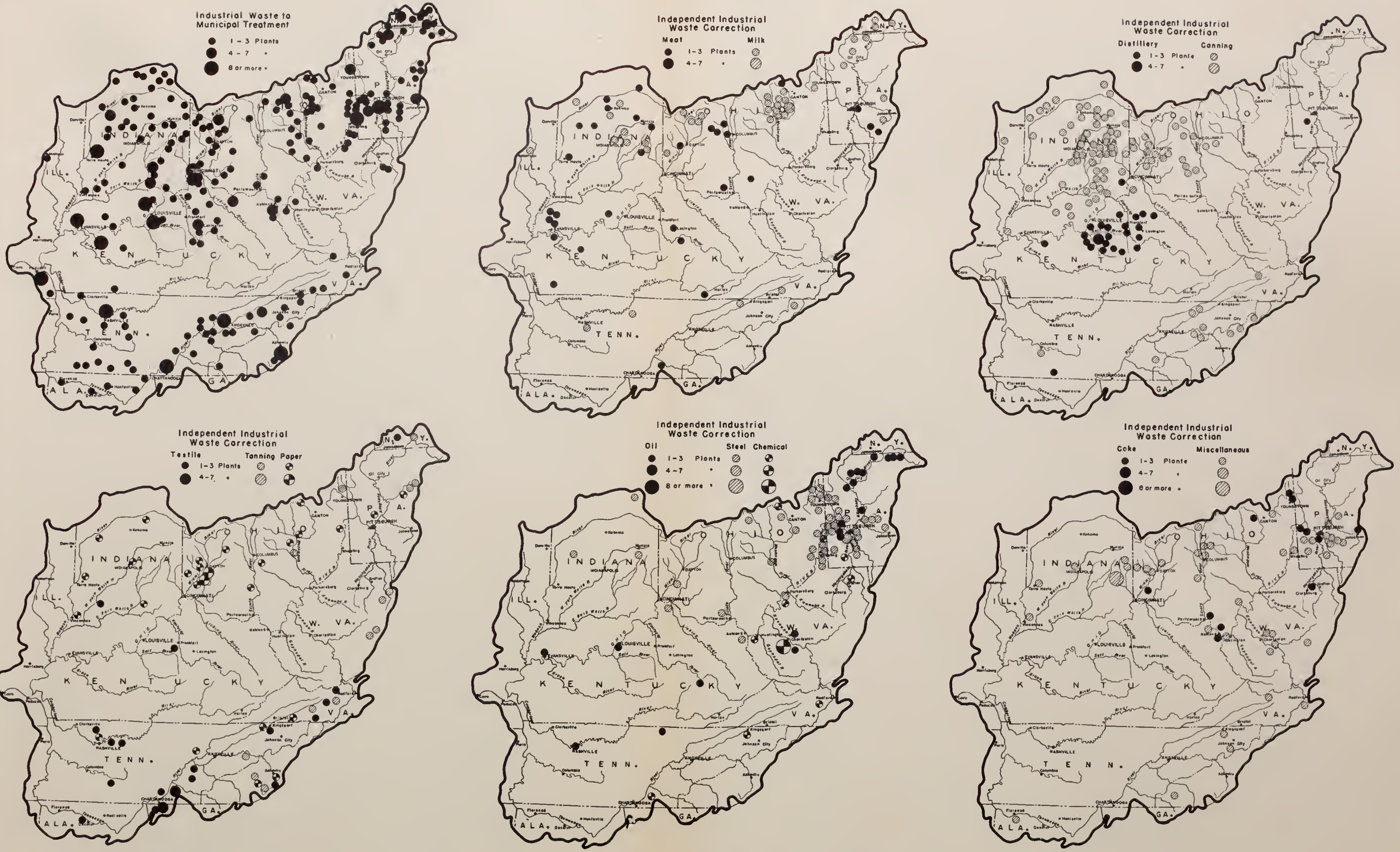
OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

FIG.-I

Fig.-1

OHIO RIVER BASIN

SUGGESTED INDUSTRIAL WASTE CORRECTION



NOTE:- Exclusive of plants where present corrective measures are adequate

OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

Table 2 Ohio River Basin - Summary Showing Industrial Wastes not Discharging to Municipal Treatment Plants, Suggested Industrial Waste Discharges to Municipal Treatment Plants and Total of Entire Industrial Waste Load in the Basin.

Industry		Number of Plants	Industrial Waste Disposal		At Least Minor Corrective Measures Taken	Estimated Sewered Population Equivalent (B.O.D.)	Suggested to Mun. Treatment	
			Munic. Sewers	Private Outlets			Number of Plants	Population Equivalent (B.O.D.)
Brewing	See Note (1)	38	35	3	27	264,300	37	263,800
By-Product Coke		23	2	21	17	745,200	2	24,300
Canning		218	52	166	160	758,900	64	310,300
Chemical		65	10	55	36	1,880,400	8	138,000
Distilling		67	14	53	53	1,009,700	20	624,600
Meat		173	76	97	115	385,700	123	323,900
Milk		253	130	123	107	85,100	167	74,700
Oil Refining		47	4	43	44	116,500	2	15,100
Paper		59	12	47	46	1,659,200	5	31,500
Steel		174	15	159	71	(2)	12	0
Tanning		32	5	27	13	269,600	13	55,400
Textile		122	57	65	10	335,100	84	216,900
Miscellaneous		333	104	229	109	160,300	89	132,500
Total		1,604	516	1,088	808	7,670,000	626	2,211,000
Industrial Wastes to Cincinnati Sewers (3)						1,108,400	-	1,108,400
Wastes Discharged to Municipal Treatment						1,195,900	-	-
Totals for the Basin						9,974,300	626	3,319,400

(1) Note: Industries occurring only once in a basin are included under "Miscellaneous" in the basin summary but are under their proper classification in this table.
(2) 336,000 pounds free acid discharged daily in waste pickle liquor.
(3) Industries not surveyed individually. Population equivalent based on comprehensive sewer gaging and sampling program of city.

Acknowledgments

The compilation of industrial waste information and the preparation of the industrial waste guides were carried out with the collaboration and assistance of numerous state officials, engineers and chemists representing municipal and private interests, equipment manufacturers, industrial management, trade associations and others. Special mention is made of the Tennessee Valley Authority, the State of West Virginia, and the Cities of Louisville and Cincinnati, who co-operated and assisted in sampling and gaging studies of industrial wastes, or made the results of such studies available. Dr. F. W. Mohlman, of the Sanitary District of Chicago, contributed results of sampling and gaging studies of that organization.

While it is not practicable to mention here all sources of information, the bibliographies of the individual guides present comprehensive listings of information sources. The National Canners Association, the State of Wisconsin and Mr. A. E. Kimberly furnished valuable information used in the cannery guide. Mr. H. A. Trebler, of Sealtest, Inc., and Mr. R. O. Henszey, of the Carnation Co., furnished information for the milk guide. Mr. W. B. Hart, of the Atlantic Refining Co., furnished information for the oil guide. Mr. C. M. Baker furnished information for the paper guide. Officials of the States of West Virginia and Pennsylvania, and Mr. Fred O'Flaherty, of the Tanners Council of America, furnished information for the tannery guide.

Personnel

The personnel of the Ohio River Pollution Survey contributing to the compilation of information on industrial waste pollution and the preparation of the Industrial Waste Guides are as follows:

H. R. Crohurst, Senior Sanitary Engineer,
  Administrative direction.
Ellis S. Tisdale, Sanitary Engineer (R),
  Technical direction.
M. LeBosquet, Jr., Senior Public Health Engineer,
  Immediate supervision of industrial waste activities and editing of all guides and revisions. Prepared drafts of Brewery, Distillery (coauthor) and Cannery (tomato, coauthor) Guides, and prepared revisions

of Coal Washery, Coke, Cotton and Distillery Guides for final report.

Samuel R. Weibel, Associate Public Health Engineer, Compiled the bulk of industrial waste information, assisted Mr. LeBosquet and prepared drafts of Meat, Milk, Oil, Paper (and Paper Pulp) and Tannery Guides.

William T. Eiffert, Assistant Public Health Engineer, Assisted Mr. Weibel and Mr. LeBosquet during 1940-41.

Gordon E. McCallum, Associate Public Health Engineer, Prepared drafts of Cannery (corn, tomato-coauthor, and peas) Guide.

George D. Reed, Assistant Public Health Engineer, Prepared drafts of Distillery (coauthor) and Coal Washery Guides, and supervised, for the U.S.Public Health Service, the co-operative sampling and gaging studies with the City of Louisville.

H. Gardner Bourne, Jr., Assistant Chemical Engineer, Prepared draft of Coke Guide, and assisted, for the U.S.Public Health Service, in co-operative studies with the State of West Virginia.

Ralph Porges, Assistant Sanitary Engineer (R), Prepared draft of Cotton Textile Guide.

Richard F. Poston, Associate Public Health Engineer, Supervised, for the U. S. Public Health Service, the co-operative sampling and gaging studies with the Tennessee Valley Authority.

Richard L. Woodward, Associate Public Health Engineer, Prepared revisions of Brewery, Cannery, Meat, Oil and Tannery Guides for final report.

Ralph C. Palange, Assistant Sanitary Engineer (R), Prepared revisions of Milk and Paper Guides for final report.

Note: Official designations apply to the last day of each person's connection with the Ohio River Pollution Survey.

OHIO RIVER POLLUTION SURVEY

BREWERY

An Industrial Waste Guide to the Brewery Industry

APPENDIX "I" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract B-1

Description of Process B-2

Raw Materials and Products B-2

Sources and Quantity of Wastes B-4

Character of Wastes. B-4

Pollution Effects. B-6

Remedial Measures. B-6

Bibliography B-8

Note Taking Form B-9

Inspection Report. B-10

Flow Diagram B-12

Abstract

Beer is produced by the fermentation of substances extracted from a mixture of malt, other prepared cereals and hops. The wastes from brewing include large amounts of cooling water; wash water used in cleaning bottles, kegs, floors, and equipment; drainage from the spent grains and hops and yeast. The spent grains and hops are disposed of separately, the grain having a considerable market value as cattle feed. The strongest wastes are the yeast and water extracted from the spent grain. Many breweries, particularly the smaller ones, sell the grain in a wet condition thereby eliminating an appreciable pollution load.

Although the waste flow per unit of product varies considerably, 300 gallons per barrel is a reasonably representative figure for breweries having to buy water and pay for waste disposal. The B.O.D. of wastes at plants where the grain is dewatered is approximately 1200 p.p.m. and suspended solids 650 p.p.m. If the grain is sold wet the B.O.D. is approximately 800 p.p.m. and suspended solids about 450 p.p.m. The following sewered population equivalents are indicated:

	Sewered Population Equivalent* Per Barrel of Beer per Day	
	Grain Dewatered	Grain Sold Wet
B. O. D.	19	12
Suspended Solids	9	6

* Based on per capita discharge of 0.167 lbs. of 5-day, 20°C. B.O.D. and 0.2 lbs. of Suspended Solids per day.

Brewery wastes can be treated effectively on trickling filters. Chemical precipitation has shown fairly good results on an experimental scale but the cost was relatively high. The only brewery waste treatment plant known which uses activated sludge has not yet shown consistent results. Most breweries are so located that their wastes can be most satisfactorily disposed of with municipal sewage. If proper provision is made in sewage treatment plant design, treatment with sewage can usually be accomplished without detriment to the municipal treatment plant.

Description of Process

Beer is an effervescent beverage resulting from the thorough alcoholic fermentation of a hopped solution, in potable water, of the extractive substances principally of barley malt, together with, if desired, other prepared cereals or their natural equivalents. Although many kinds of beer are made the processes in common use in this country today are fairly well standardized.

The barley malt is usually purchased by the brewery. (Malting establishments are concentrated in or near the barley-producing areas in Wisconsin, Minnesota and other north central states.) The malt is mashed by subjecting it to the action of water with heating and stirring to extract the desired substances by effecting the inversion of the starch into maltose, malto-dextrin, and dextrin and by the modification of some of the insoluble albuminoids into soluble ones. The enzymes, diastase and peptase in the malt are the agents which bring about these changes. The unmalted cereals (usually rice and corn) are added during mashing. After the mashing has been completed the mixture in the mash-tub is allowed to settle after which the extract, the wort, is drawn off through the settled solids. These solids are then sprayed with hot water (sparching) to recover additional wort. The wort is boiled, hops added, and the boiling continued. The boiling helps to clarify the wort and to remove certain undesirable constituents. The wort then goes to the hop back where the spent hops are removed. It is cooled and aerated, yeast added and the mixture allowed to ferment. When the fermentation is completed, the beer is cooled again and stored in cellars where a low temperature is maintained for aging. When sufficiently matured it is clarified and carbonated. The beer is then ready for packaging in kegs or bottles.

Raw Materials and Products

Raw Materials

(a) Malt, about 36 pounds per barrel (31 gallons) of beer. The average quantity of malt used by 35 breweries in the Ohio Basin was 34 pounds per barrel and varied from 25 to 44 pounds per barrel.

(b) Unmalted cereals, usually corn or rice grits, but occasionally other cereals such as wheat or rye. Cereal sugars or syrups also are used, particularly corn syrup. One plant in the Ohio Basin used soy bean meal. About 14 pounds of these materials are used per barrel of beer. The average quantity of unmalted cereals and syrups used by 35 breweries in the Ohio Basin was 12 pounds per barrel and this varied from 8 to 18 pounds per barrel.

(c) Hops or hops extract, about 0.6 pounds per barrel of beer. The average quantity of hops used by 34 breweries in the Ohio Basin was 0.6 pounds per barrel and varied from 0.4 to 1.0 pounds per barrel.

(d) Yeast, about one pound per barrel.

Products

The standard unit of production of beer is the barrel, containing 31 U. S. gallons. The total national production for the year ending June 30, 1940 was 54,891,737 barrels. Six hundred and eleven breweries were in operation during that year. Forty-four breweries surveyed in connection with the Ohio River Pollution Survey produced about 4,150,000 barrels per year. The smallest ones produce about 10,000 barrels and the largest ones more than 500,000 barrels per year. About half of the beer sold is in bottles and the other half is sold as keg beer. The increase in the amount of beer bottled has been marked in recent years.

Employees

The number of employees per unit of production varies greatly. The average of 44 plants in the Ohio Basin was 1,090 barrels per plant employee per year but this figure varied from 340 to 2,130 barrels. In some instances these variations are due to the inclusion of employees of ice plants or soft drink bottling plants operated in conjunction with the brewery. In others, little or no bottling is done with a corresponding increase in beer production per employee. More than half of the breweries surveyed showed productions per employee of between 700 and 1,400 barrels per year.

Sources and Quantity of Wastes

The average amount of wastes from 23 breweries in the Ohio Basin on which reasonably accurate data were available was 470 gallons per barrel of beer. Two plants which bought all water from public supplies used less than 200 gallons per barrel whereas several which had private wells for at least part of their supply used more than 700 gallons per barrel. In a few instances water usage in excess of 1,000 gallons per barrel were reported but since these figures were of doubtful accuracy they were not included in the above average although these high figures are not improbable. The principal cause of these variations is a variation in the amount of cooling water used. Mohlman found the average waste flow from 28 Chicago breweries to be 320 gallons per barrel, varying from 180 gallons in winter to 500 gallons in summer. A Houston, Texas brewery, where the wastes are treated in an industrial waste treatment plant, produces about 280 gallons of waste per barrel.

The largest quantity of wastes from breweries is usually unpolluted cooling water. Wash waters for equipment, kegs, bottles, etc. contain varying amounts of wort or beer, yeast and acid or alkaline cleansing agents. Since absolute cleanliness of the equipment is essential the wash water comprises an important part of the waste flow. The residue from the mashing vats contains the spent grains. This grain is always recovered and sold either in a wet or dry state. The waste from dewaterin this grain, if it is sold dry, is the strongest waste from a brewery. Mohlman found that this waste amounted to about 7.5 percent of the total waste flow. Spent hops occasionally discharged to the sewer and at least a part of the yeast which settles to the bottom of the fermentors is usually discharged with the other wastes. Spills or wastage of spoiled brews are other sources of wastes.

Character of Wastes

The Chicago studies indicated that brewery wastes have a sewered population equivalent, based on 5-day B.O.D., of 19 per barrel of beer produced per day. Three one-day tests at the Minster, Ohio brewery showed a sewered population equivalent of from 6.4 to 15 per barrel, per day, and an average of 11. The grain at this brewery is sold wet. A two-day test at a Louisville brewery showed a population equivalent of 12 per barrel per day, exclusive of bottling wastes. At the Houston, Texas plant, where the grain is sold wet and about 90 percent of the product is bottled, the population equivalent was found to be about 14 per barrel per day during experimental studies. Operating results at the waste treatment plant indicate a population equivalent of about 12 per barrel per day.

The Chicago studies showed the average suspended solids content of the brewery wastes to be 1.68 pounds per barrel, of which 31 percent was from the grain dewatering wastes. This corresponds to a sewered population equivalent of 8.4 per barrel per day, if the grain is dried, and 5.8 per barrel per day if the grain is sold wet. The Louisville brewery where the grain is dried showed a suspended solids population equivalent of 6 per barrel per day exclusive of bottling wastes. At the Houston and Minster breweries, where the grain is sold wet, the suspended solids population equivalents were 5.5 and 2.6 per barrel per day respectively.

Typical analytical results on brewery wastes are as follows:

Determination	Chicago Studies		Louisville	Minster	Houston
	Grain Squeezer Waste	Total Waste	Total Waste	Total Waste	Total Waste
B.O.D. p.p.m. (5-day 20°C.)	25,700	1,200	419	1,028	858
Suspended Solids ppm.	8,550	650	244	305	411
Total Nitrogen p.p.m.	860	50	-	24	-
pH	4.1	6.1	7.4	5.5	-

Because of the more extensive sampling involved in the Chicago studies, these must be given more weight in determining average waste discharges than the other studies. The sewered population equivalent of typical brewery wastes on a B.O.D. basis averages about 19 per barrel per day if the grain is dewatered and 12 if sold wet. The corresponding suspended solids population equivalents can be taken as 9 and 6.

Pollution Effects

The polluting effects of brewery wastes are almost entirely due to the oxygen demand which they impose on the receiving stream. The wastes are often slightly acid but not to any important degree. The wastes contain numerous bacteria, none of which are harmful, and large numbers of yeast cells.

Remedial Measures

Brewers grains are always recovered. They have a considerable market value as cattle food. In the Ohio Basin, more than half of the breweries sell the wet grain. The larger ones and most of those in large cities are obliged to dry the grain because of the lack of an adequate local market for the grain. Selling the wet grain reduces the waste load appreciably. Spent hops also are sometimes sold to farmers for fertilizer although they have no great market value. The commonest methods of disposal are dumping on land and incineration. A part of the yeast from the fermentors often is reused in the process but from one-half to two-thirds of the yeast is wasted to the sewer. Recovery of this would effect an important reduction in the waste load.

The wastes are amenable to treatment by the common biological sewage treatment processes. Experimental studies at Houston showed that the primary sedimentation tanks preceding trickling filters reduced the B.O.D. and suspended solids by about 18 percent. Chemical treatment with various coagulants reduced the B.O.D. by from 50 to 75 percent but the results were erratic, large volumes of sludge were produced, and the sludge did not filter readily on a vacuum filter. The Hays process was also tested but B.O.D. reductions were found to be low and suspended solids reductions somewhat poorer than achieved by trickling filters. Trickling filters were found to give excellent results. Series operation of twin filters gave better results than parallel operation. With loadings of 15 pounds of 24 hr. B.O.D. per 1,000 cubic feet of filter per day (equivalent to about 36 pounds of 5-day B.O.D., based on parallel B.O.D. determinations) reductions of 90 percent in B.O.D. were found. On the basis of the experimental work a trickling filter plant was designed providing:

(a) Twin settling tanks providing detention periods of 1.5 hours each at maximum flows of 600,000 gallons per day.

(b) Twin dosing tanks.

(c) Twin circular trickling filters 100 feet in diameter and 6.5 feet deep equipped with rotary distributors. The filter media is 1¼"-2½" granite. Filters designed for maximum loadings of 12.8 pounds of 24 hr. B.O.D. per 1,000 cubic feet of filter media per day.

(d) Final settling tank designed for 650 gallon overflow rate.

(e) Sludge digestion tanks, unheated.

(f) Sludge drying beds, pumps, etc.

This plant was constructed at a cost of about $70,000 and was placed in operation in November, 1938. The filters and settling tanks have been operated in series. Sludge from the secondary and final settling tanks is concentrated in the primary settling tank before being pumped to the digester. The flow has averaged 280,000 gallons per day, the B.O.D. 882 p.p.m., and suspended solids 458 p.p.m. The plant has averaged about 92 percent removal of B.O.D. and 85 percent removal of suspended solids. The operating costs have been about two cents per barrel of beer. Operating charges on such a plant are relatively constant and do not vary greatly with variations in production.

An activated sludge treatment plant was installed at the Minster, Ohio brewery in 1936. The plant includes provision for preliminary chemical coagulation. Numerous operating difficulties have been encountered and, as yet, consistent results have not been obtained.

By far the commonest method of disposal of brewery wastes is to municipal sewers. Most breweries are located in the larger cities and are accessible to sewers. Only two of the breweries in the Ohio Basin are so situated as to require independent treatment. Since the treatment methods used are similar to those used for municipal sewage, there seems to be no reason why brewery wastes cannot be treated satisfactorily at municipal treatment plants if they are designed for the additional waste load and if the plant is carefully operated. There is some indication that activated sludge plants are less satisfactory than trickling filters for secondary treatment of sewage containing large amounts of brewery wastes.

Bibliography

1. F.W.Mohlman, "Brewery Wastes," Modern Brewer, 21,35-37 (January, 1939.)

2. R.J.Bushee, "Treatment of Brewery Wastes," Sewage Works Journal, 11, 295-307 (March, 1939.)

3. S.L.Tolman, "Operation of the Waste Treatment Plant of the Gulf Brewing Company, Houston, Texas," Ohio Conference on Sewage Treatment, 14th Annual Report.

4. Correspondence with Gulf Brewing Company, Houston, Texas, F.P.Brogniez, Master Brewer, and L.L. Hahn,Jr., Chemist.

5. Correspondence with Ohio State Health Department, F. H. Waring, Chief Engineer.

6. Ohio River Pollution Survey, unpublished data.

BREWERY WASTES (Not an Actual Brewery)

Plant Openshaw Brewing Co. State Ohio Ref.No. RB - 89

City Palliston County Marshall Main Watershed Rapid River

Address 4th and Paragon Sts. Sub-watershed Beaver Cr.

Informant F. A. Openshaw Title Brewmaster Principal Product Beer

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	40	280	40
Maximum	48	132	50

Seasonal variation Peak Months May to Sept. inclusive

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	Municipal Supply	Total - All Purposes	Total - All Purposes	Filtered Chlorinated
Industrial	"	60,000 g.p.d.	80,000 g.p.d.	
Cooling	"			

RAW MATERIALS: - Malt 1,850,000 lb. per year Rice 500,000 lb. per year

Corn 120,000 lb. per year Hops 30,000 lb. per year

Yeast Other 45,000 Caustic Soda 18,000 lb. Tri-Sodium Phosphate per year for cleaning

PRODUCTS: - Beer 210 bbl. per brew Brews per week: Average 5 Maximum 6

52,000 bbl. per year Percent of Product Bottled

WASTES: - Quantity 70,000 g.p.d. (max.) How estimated Water Consumption

Brewers grain No Data available Disposal Sold to Farmers (wet)

Spent Hops " " " Disposal City Dump

Yeast " " " Disposal Sewer

Treatment To Municipal Treatment Plant

Analyses: Number None Date By whom

Appearance Could not inspect

OUTLET:- Where to City Sewer (4th Street) through 15" Plant Connection

Description:	Size and Shape	Material	Location	Elevation
1.				
2.				
3.				

Gaging possibilities Poor

Conditions below outlet: Color ———

Turbidity ——— Deposits ———

SANITARY SEWAGE: Disposal To City Sewer Persons tributary 60

REMARKS Water Consumption Lower than Average because of Necessity of Buying all Water and of Paying Sewer Rental Based on Water Consumption.

Survey by George Spelvin Date 8-29-39.

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES

River Mileage Index No. RB 89

Type of Plant Brewery State Ohio

Name of Plant Openshaw Brewing Co.

Municipality Falliston Main Watershed Rapid

County Marshall Subwatershed Beaver Creek

Address 4th & Paragon Street

Source of Information F. A. Openshaw, Brewmaster

Plant Operation:- Ave. 40 hr. per week - 40 plant employees
Max. 48 hr. " " - 50 " "

Seasonal Variation:- Peak months - May 1 - Sept. 30

6 Brews per week - 210 bbl. per brew.

(Survey report continued on next page)

Survey by George Spelvin Date 8-29-39

Sewered Population Equivalent Computation:-

Factors used per 31 gal. bbl. of beer produced.

B.O.D. 12 Suspended solids 6

Sewered population equivalent* based on B.O.D. 2,500

Sewered population equivalent* based on suspended solids 1,300

Remarks: Grain sold wet. Wastes to municipal treatment.

Computation by: G.P.G. Date 7-3-40. Cincinnati Office

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
*Rounded to nearest 100.

Openshaw Brewing Co.,
Palliston, Ohio.

Water Supply - Ave. - 60,000 gallons per day.
Max. - 80,000 gallons per day.

All water from municipal supply.

Raw Materials - 185,000 lbs. malt per year.
50,000 lbs. rice grits per year.
12,000 lbs. corn flakes per year.
30,000 lbs. hops per year.

Chemicals (per year) for cleaning
45,000 lbs. caustic soda.
18,000 lbs. tri-sodium phosphate.

Products - 52,000 barrels of beer per year.
210 gallons per brew. Maximum of one brew per day.

Wastes - Spent grains sold to farmers (wet).
Spent hops to city dump.
Yeast wasted to sewer.
Cooling water recirculated (refrigeration).
Maximum waste flow about 70,000 gallons per day.
(350 gallons per bbl.)

Outlets - To city sewers and treatment plant.
1 - 15" connection to 4th Street sewer. No manhole on plant sewer. Gaging opportunity poor.

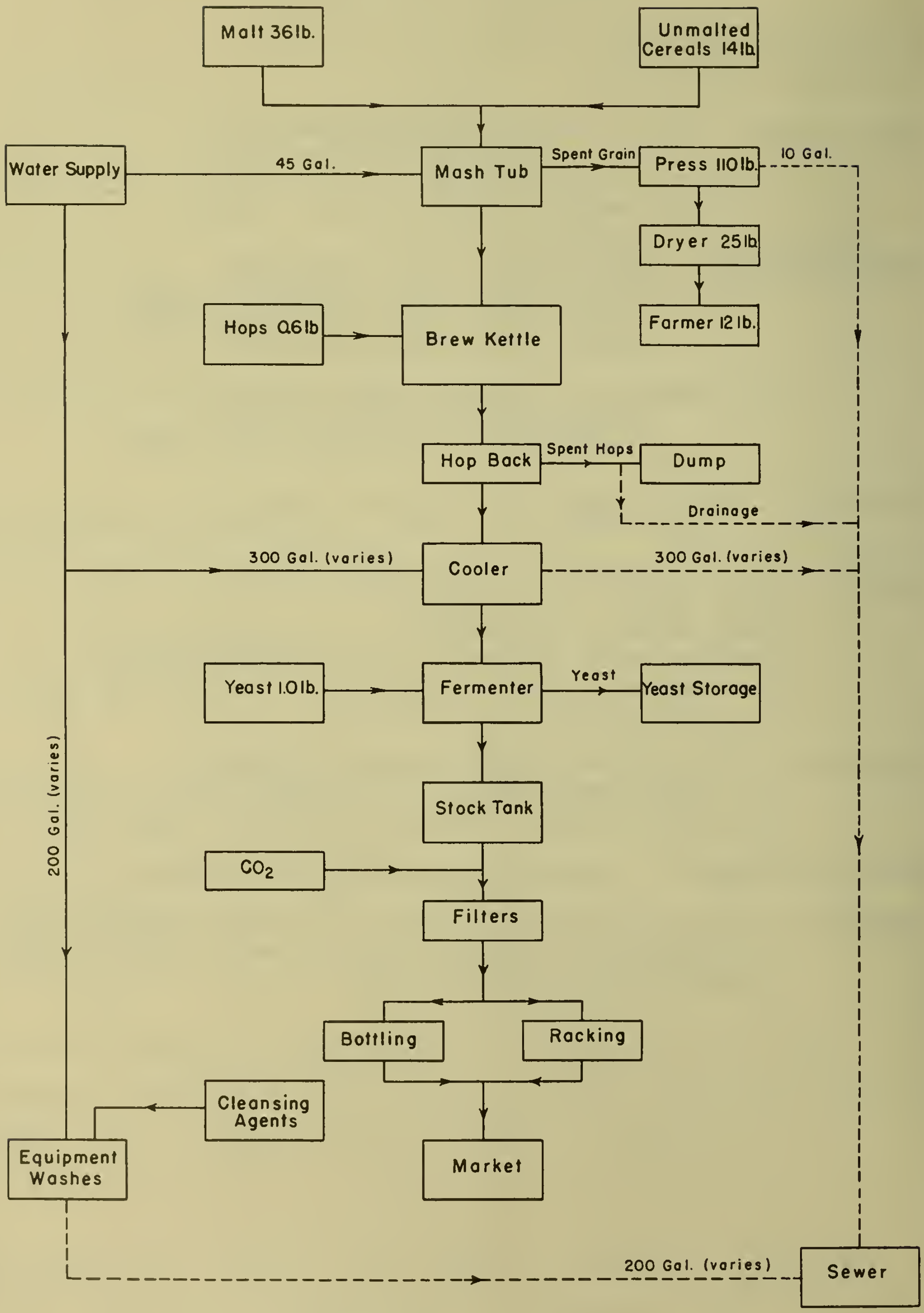
Sanitary Sewage - With plant wastes to city sewers.

Remarks - Water consumption lower than average because of necessity of buying all water and of paying sewer rental based on water use.

Flow Diagram

BREWERY

Quantities per 31 gal. Bbl. Beer



OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

CANNERY

An Industrial Waste Guide to the Canning Industry

APPENDIX "II" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

	Page
Abstract	Cn-1
Description of Process	Cn-4
Raw Materials and Products	Cn-9
Sources and Quantity of Wastes	Cn-11
Character of Wastes	Cn-15
Pollution Effects	Cn-16
Remedial Measures	Cn-16
Bibliography	Cn-35
Note Taking Form	Cn-37
Inspection Report	Cn-38
Flow Diagram	Cn-40

List of Tables

Cn-1	Representative Waste Flows and Strengths from Canneries Producing Various Products	Cn-3
Cn-2	Sewered Population Equivalent of Cannery Wastes Based on B.O.D. and Suspended Solids	Cn-16
Cn-3	Chemical Precipitation Results, Straight Factory Run Wastes	Cn-19
Cn-4	Results Obtained by the Chemical Treatment of Corn Waste, in Quantities of 11,350 Gallons	Cn-20
Cn-5	Results Obtained by the Treatment of Pea Waste with Various Chemicals, in Quantities of 100 Gallons	Cn-22
Cn-6	Results of Operations Using Chemical Precipitation and One-Hour Batch Settling Followed by High Rate Trickling Filters	Cn-27
Cn-7	Results Obtained by High Rate Trickling Filter Treatment of Corn and Tomato Wastes	Cn-28
Cn-8	Treatment of Pea Cannery Wastes on Trickling Filters at Albion, N.Y.	Cn-29
Cn-9	Results Obtained by High Rate Trickling Filter Treatment of Pea Canning Waste	Cn-29
Cn-10	Results of Intermittent Sand Filtration of Corn, Succotash, and Lima Bean Wastes	Cn-30
Cn-11	Monthly Average Results of Treatment of Sewage, Cannery Waste and Milk Wastes at Celina, Ohio Municipal Treatment Plant, 1940	Cn-31

Abstract

The canning industry is highly seasonal, most canneries operating on only one or two products, with a working season of from one to three months per year. Some of the larger establishments operate throughout the year by canning such products as dried beans, hominy, and spaghetti during the periods when fresh vegetables or fruits are not in season.

Wastes from fruit and vegetable canneries consist primarily of wash water used to clean the raw material, floors, and equipment, water used in blanching, and spills of product at various points along the processing line. The wastes contain small bits of the product, pieces of skin, seeds, hulls, juice, etc., and have a color characteristic of the product being packed. The principal products canned in the Ohio Basin are tomatoes (and tomato products), corn, and peas.

The amount and strength of the wastes from canneries varies greatly but it is possible to estimate approximately the pollution load from a cannery of a given type in terms of its production. Representative figures representing the magnitude and strength of cannery wastes are shown on Table Cn-1.

Variations of as much as 400 percent in the pollution load per unit of production have been found. The existence of this variation indicates a promising line of attack in correcting pollution at canneries whose wastes are greater in strength and magnitude than other canneries of the same product. Care in preventing the entrance of the stronger wastes, juice, garbage, etc., into the sewers can often accomplish substantial reduction in the waste load without treatment.

Fine screens (about 40 mesh) should be provided at every cannery, regardless of the method of waste disposal, to remove the coarser solids from the wastes. In general, these solids are light and do not settle well but float and form a scum. The fresh wastes are usually about neutral (varying of course with the pH of the water supply) but in a short time they become acid. Fresh wastes are much easier to treat.

Lagooning, often the only practical procedure at a small cannery, has proven an effective method of abating pollution at small rural canneries where the operating season is short, sufficient land available and odor nuisances unimportant. Sodium nitrate, suggested earlier in one of these guides, has been used to control odors.

Chemical precipitation is extensively used in cannery waste treatment. Low annual charges, even at the expense of high operating costs, makes this process attractive in the seasonal canning industry. Lime alone, or with alum or various iron salts, are the principal chemicals used. The primary consideration in such treatment has been found to be raising the pH of the wastes to about 10. Reductions in B.C.D. of about 50 percent are common with this type of treatment. The undigested sludge dries in a week or less on open beds.

Trickling filters are not widely used in cannery waste treatment although numerous experiments have shown that they can accomplish B.C.D. reductions of the same order as they can in treating domestic sewage. The time required to reach peak efficiency is the principal difficulty with trickling filters in treating cannery wastes.

Some municipal treatment plants are successfully treating canning wastes in volumes considerably in excess of the ordinary domestic sewage. Chemical treatment, either at the cannery or at the treatment plant, has been found almost essential if the cannery wastes represent an appreciable portion of the total waste load. Both trickling filters and activated sludge plants are being used successfully where complete treatment is required. Adequate design of the secondary devices on the basis of the B.C.D. loading is essential.

The cost of treating cannery wastes varies quite widely. In general, it is of the order of magnitude of one cent per case or less. In some cases, however, it may amount to as much as two cents or more per case. Lagooning, where it is at all practicable, is usually the cheapest method. Chemical treatment costs considerably more, and trickling filters still more.

Table Cn-1 Representative Waste Flows and Strengths from Canneries Producing Various Products

Product	Waste flow gal. per case (1)	B.O.D. 5-day 20° C. p.p.m.	Susp. Solids p.p.m.	Sewered Pop. Equivalent per 100 cases per day(1)	
				B.O.D.(2)	Suspended Solids (2)
Asparagus	70	100	30	35	9
Beans-Pork and	35	925	225	160	33
Green	35	200	60	35	9
Lima	250	190	420	240	440
Beets	37	2,600	1,530	480	235
Corn-Cream Style	25	620	300	75	30
Whole Kernel	25	2,000	1,250	250	130
Peas	25	1,700	400	210	40
Pumpkin-Squash	(4) 25	6,400	1,850	800	190
Sauer Kraut	3	6,300	630	100	8
Spinach	160	615	-	490	-
Succotash	125	525	250	330	130
Tomatoes-Whole	7.5	4,000	2,000	150	60
Products	70	1,000	500	350	150
Apricots	(5) 80	1,020	-	410	-
Grapefruit-Sections	56	1,850	270	520	63
Juice	5	(3)310	170	8	3
Peaches-Pears	(5) 65	1,340	-	440	-

(1) Case of 24 - No. 2 cans except as noted.

(2) Based on per capita discharge of 0.167 lbs. of 5-day B.O.D. and 0.2 lbs. Suspended Solids per day.

(3) Exclusive of peel bin wastes.

(4) Per case of 24 - No. $2\frac{1}{2}$ Cans.

(5) Size of can unknown.

Description of Process

Fruit and vegetable canneries are important sources of industrial wastes. The nature of the industry requires that large amounts of water be used to ensure cleanliness of the product. On the whole, the industry is growing. There are about 3,000 such establishments in the United States and about 250 were visited during the Ohio River Pollution Survey. Although a wide variety of foods are canned, the most important ones in the Ohio River Basin are tomatoes, corn, and peas. The pollution problems attending the canning of these products are discussed in this guide and some additional information on the canning of other products is included.

Corn

Corn is planted in the early summer and harvested between the middle of August and the latter part of September. (1) The grower delivers the ears in husks to the cannery where it is weighed, unloaded, and sent to the storage bin. From the storage bin the corn goes to

(a) Huskers which remove the husks, butts, and silks. These are conveyed to a stack or silo. The corn passes on to the

(b) Sorters and Trimmers who remove foreign material, defective ears and parts. The refuse goes to the stack or silo and the corn passes on through the

(c) Washer where, by a process of rolling and scrubbing under powerful water sprays, loose husks, dirt, etc., are removed.

(d) Cutters cut and scrape the kernels from the cob, which is sent to the stack or silo. The kernels move on to the

(e) Silker, a device consisting of screens and shakers, which remove any remaining silks. These are discharged to the stack or silo. The corn is sent to the

---

(1) These dates apply to conditions in the northern half of the Ohio River Basin. In other climates growing seasons and time of harvest are different.

(f) Batch Mixer (Fill and Draw Type) in which brine is added to the corn in a ratio of about 1 to 4. The contents of the mixer are agitated and preheated to a temperature of 180°- 190° F. before being pumped to a

(g) Blending Mixer (Continuous Flow Type), the purpose of which is to maintain uniformity of product. The mixture is pumped to the

(h) Filler which fills the cans. These then go to a

(i) Closing Machine, which seals covers on the cans. The cans are cooked in a

(j) Retort where steam is used to maintain a temperature of about 250°F. for about 70 minutes. After cooking, the cans are

(k) Cooled, sometimes in the retorts by removing the covers and applying water, but more commonly in a long cooling tank through which the cans pass on a conveyor.

After cooling, the cans are cased and stored in the warehouse. Before being shipped the cans are passed through a shaking machine to break up the contents and through a labeling machine.

The average time from the truck to the warehouse is about two hours, of which seventy minutes is spent in the retorts and about 20-25 minutes in the cooling tank.

The above process applies to the canning of cream style corn which constitutes the bulk of the corn pack. In packing whole kernel corn, bleeding of the cream from the kernel is minimized by a special cutting process and the juices adhering to the kernels are washed away.

Peas

Peas are usually planted during April and require a 50-75 day growing season. The harvest seasons in Ohio and Wisconsin vary from June 1st to July 10th and June 15th to August 10th, respectively.

The vines are cut with a mowing machine, raked or bunched and loaded on truck or wagon by which they are transported as quickly as possible to vine stations to prevent wilting. Vining may be done at the cannery or at several centralized locations in the growing area. The latter practice has some definite advantages. Long hauls to the cannery and back to the farms for animal feeding are eliminated; vine stacks are smaller and are located where the soil usually is able better to absorb stack juices before they reach a natural watercourse. The viner removes the vines and pods and delivers the shelled peas to boxes. These are now ready for the cannery processing line.

The operations in a pea canning factory are usually as follows:

(a) Weighing Scales

(b) Clipper, Screen or Cleaner - Pieces of pods, stems and leaves are removed by screens and blown away.

(c) Washer - Squirrel cage type, inside of which is perforated pipe delivering heavy water spray. In some plants a riffler precedes the squirrel cage as part of the washing process.

(d) Grader - Where grading for size is accomplished by passing through rotating cylinder screens or by a flotation process in brine solutions.

(e) Blancher - A perforated cylinder containing a spiral. The cylinder is rotated at a speed which will pass the peas through in a given time. Water and steam are admitted at the downstream end and discharged at the inlet end of the cylinder. The time of blanching depends on the size and condition of the peas, varying between 5 and 15 minutes. The blanching temperature maintained in any particular cannery appears to be kept fairly constant. Some canners blanch at 180°F. - 190°F. and others at 208° F. - 212° F. The percentage of splits is said to be higher at the higher temperatures. The peas are discharged from the blancher to a

(f) Washer - for separation of split peas and water.

(g) Picking Table - where any remaining foreign material, split or bruised peas are removed manually.

(h) Filler - brine is added, and the can filled.

(i) Closing Machine - seals the cover on the can.

(j) Retorts - cooking at about 240° F. for 30-35 minutes. Some packers use a slightly lower temperature and shorter cooking period. Upon completion of the cooking process the cans are placed on endless conveyors carrying them through the

(k) Cooling Tank - which is expected to bring the temperature of a No.2 can below 100° F. in about 7 minutes. About 25 minutes are required to reduce the temperature of a No.10 can below 100° F.

After cooling, the cans are cased and stored in the warehouse. Labeling is usually done at the time of shipment. Under normal operating conditions the complete process takes less than one hour.

Tomatoes

Tomatoes are planted or transplanted in the early summer and harvested between the middle of August and the latter part of September. As the tomatoes ripen, they are picked, placed in 5/8 bushel (29-34 lbs. net) hampers, and delivered to the cannery.

The process of canning whole tomatoes usually consists of the following steps:

(a) Soak Tank - containing clear water which softens and loosens dirt and foreign matter. After a brief detention period (3-5 minutes) air, applied through perforated pipes in the bottom of the tank, raises the tomatoes to the elevation belt at the downstream end of the vat. The conveyor carries them under

(b) Water Sprays which remove dirt and foreign material loosened in the soak tank.

(c) Picking and sorting table - off color, damaged and defective fruit are removed manually.

(d) Water Spray - The second spray removes any remaining dirt or foreign matter.

(e) Scalder - (hooded conveyor) in which live steam is applied to the tomatoes for periods of 15 seconds to 2 minutes, (depending on the head of steam available and condition of the tomatoes) to loosen the skin on the fruit.

(f) Cold Water Spray - to loosen further the skin and check the heat in the fruit.

(g) Peeling and Coring Table - skins and cores are removed.

(h) Fillers (usually hand operation on whole tomatoes) Salt is added at the rate of about 25 grains per No. 2 can (20 oz.). Tomatoes are placed in the can and voids filled with juice.

(i) Exhauster - a covered conveyor containing steam jets. The temperature is maintained between 150° F. and 180° F. for a period of 3 to 5 minutes.

(j) Closing Machine - seals the cover on the can. Cooking may be accomplished in retorts but more general practice is by the use of a

(k) Continuous Cooker - a long, narrow tank containing water at a temperature of 212° F. The cans in small wire crates pass through the tank on a conveyor. The time of cooking is generally 20-30 minutes, depending on the ripeness of the tomato. The crates of cans are arranged in open stacks for

(l) Air Cooling -

In the processing of most tomato products peeling is omitted. The process in making tomato pulp is the same as that of whole tomatoes through the scalder, (a) to (e) inclusive. The scalded tomatoes pass to a

(f) Pulper - which removes skins, seeds, and cores.

(g) Cooker - (fill and draw type) consisting of a large wooden or copper tank (may be under slight vacuum) heated by steam passing through copper coils at a pressure of 100 lbs. or more per square inch. Cooking and evaporation is continued until a specific gravity of from 1.035 to 1.050 is reached.

(h) Finishing Machine - consisting of fine screens which remove any foreign material.

(i) Holding Tank equipped with heating coils at temperature 180° F. to 190° F. and agitating units.

(j) Filler - Salt is added as cans are filled.

(k) Closing Machine - which seals the cover.

(l) Cooker or Sterilizer - This step may be omitted.

(m) Air Cooling -

The manufacture of catchup is very similar to that of pulp except that salt, vinegar, sugar, and spices are added to the cooker. Tomatoes are not peeled nor cored for catchup production. Catchup is usually packed in glass and often sterilized or cooked briefly after closing.

Chili sauce differs from catchup in that the tomatoes are peeled and cored as for canning whole tomatoes. They are then run through a chopping machine. More onions, garlic, and peppers are generally employed in the spicing and spices may be placed in a sack which is later removed. The cooking and handling are similar to that used for catchup, but the finishing operation (fine screening) is eliminated. Packing in glass is customary.

Raw Materials and Products

Corn

The raw materials used in corn canning are corn and brine. The brine is made up according to the desires of the plant superintendent. It usually contains from 10 to 20 pounds of salt and from 50 to 100 pounds of sugar per 100 gallons of water.

Under average conditions a ton of corn as received at the cannery produces about 665 No.2 cans (net weight 20 oz. per can). Since about 20 percent of the volume is brine the net weight of the canned corn from one ton of material as received is about 665 pounds and the loss between raw material and product about 67 percent. The flow diagram shows the approximate amounts of various substances lost during the process and the method of disposal of each.

Peas

The raw materials used are graded peas and brine. Brine is made up according to grade of product packed. Ten pounds of salt and 20-25 pounds of sugar per 100 gallons of water appears to be a fair average of ingredients used. This solution is added to the peas at the filler in the ratio of about 1 to 2. A 20-oz. (net weight) No. 2 can usually contains 12-14 ounces of peas and 6-8 ounces of brine.

In packing standard grades a yield of 2,400 No. 2 cans per ton of shelled peas may be expected. If each can contains 13 oz. of peas, the loss between raw material and product would be 2 percent. In packing fancy grades about 2,000 cans of No. 2's may be expected from a ton of shelled peas. On the basis of 13 ounces per can, the loss between raw material and product would be 18 percent. Losses are said to vary between 2 and 15 percent during processing.

Tomatoes

In processing whole tomatoes the number of No.2 cans per ton will vary from slightly under 700 to over 1,100. On an average 900-1,000 cans per ton is expected. Salt is added at about 25 grains per No.2 can. Other ingredients, such as sugar and spices, added to tomato products are not in quantities sufficient to affect the weight of the final product.

Using 950 cans per ton as an average, the weight of product derived from one ton of tomatoes as delivered at the plant would be 1,187 pounds or a loss of about 40 percent. The principal losses are represented by defective, bruised or badly damaged fruit (culls), skins, cores, and seeds.

Losses on tomato products appear, in general, to be somewhat higher than those on whole tomatoes. In studies at an Ohio cannery, Kimberly found the losses on pulp and juice to be slightly over 50 percent. It is probable that this loss will vary from around 40 percent to over 50 percent on all tomato products, depending on the condition of the raw material. Considerable amounts of tomato products are bottled in glassware. It is possible that breakage of filled glass containers may increase the percentage of loss.

Employees

About 90 employees are required to operate a one-line corn cannery receiving 75 tons of corn and packing 2,000 cases of 24 No.2 cans per day. The ratio of employees to product is usually between 3 and 6 employees per 100 cases per day. This ratio is low in the larger plants and high in the smaller ones.

Twenty-five or thirty employees can operate a one-line pea cannery, packing fancy grades, which of course require more sorters than are needed on standard grades. One cannery official in Ohio estimated that a plant packing standard grades could operate one line with a minimum of 10-15 employees. The average daily pack in a one-line plant would be about 2,000 cases of No.2's. The ratio of employees to product would then be 5-15 persons per 1,000 cases of product. More persons are employed per unit of product in a one-line plant than in a plant operating several lines.

A one-line tomato cannery receiving 40 to 50 tons of tomatoes per day and packing 1,500 to 2,000 cases of No.2 cans of whole tomatoes will usually employ between 90 and 120 persons. Peeling and coring require 70 to 90 persons; about four are required for sorting and the remaining employees have various other duties. The ratio of employees to product is 5 to 8 persons per 100 cases of No.2 cans packed per day. On products where the tomatoes are not peeled, the ratio is much smaller.

Sources and Quantity of Wastes

All three types of canneries have two types of waste in common; the continuous flow of wash water used in the canning operation and the wastes from the general cleanup of floors, tables and equipment at the end of the days run or more frequently. Wastes more or less peculiar to the various products are as follows:

Peas	- Blancher wastes. This is a continuous discharge and, in addition, the blancher is dumped periodically.
Tomatoes	- Soak tanks. These are dumped periodically.
Corn and Peas	- Silage liquor. Drainage from stacks and silos produced by the decomposition of husks, cobs, vines, pods, etc.

If the cans are water-cooled, the cooling water adds to the volume of wastes but it is unpolluted. In some canneries cooling water is reused.

The amounts of water used in various canneries of the same general type varies greatly depending on such factors as the method of cooling, type of equipment, housekeeping methods, adequacy and cost of water, and method and cost of waste disposal.

The bulk of the wastes (exclusive of cooling water which presents no pollution problem) comes from the washing operations and from the general cleanup of floors and equipment.

Corn

Corn canneries inspected in connection with the Ohio River Pollution Survey indicated an average waste flow of about 25 gallons per case which amounted to about 60 to 65 percent of the total water used. Studies of a cannery at Canal Winchester canning cream style corn showed an average waste flow of 23.8 gallons per case exclusive of 16.7 gallons per case of condenser and cooling water. The waste flow during the 11-day test varied from 14.0 to 43.3 gallons per case and the condenser flow varied from 10.2 to 23.8 gallons per case. A two-day test indicated that wastes from the cleanup at the end of the day amounted to about 1.5 gallons per case.

Four Wisconsin canneries reported an average waste flow of 24 gallons per case over a four-year period. The Cedarburg, Wisconsin cannery reported a waste flow of 20 gallons per case during the 1938 canning season. These flows are exclusive of cooling water.

No data are available on the exact amount of silage liquor produced but the quantity is known to be small.

Peas

Pea canning produces approximately the same amount of waste per case as corn canning. The Wisconsin State Board of Health states that a two-line pea cannery packing 100,000 No.2 cans per day will use about 100,000 gallons of water. Eldridge gives a volume of 25 gallons per case.

Studies in Wisconsin during the past seven years indicate an average waste flow of slightly more than one gallon per No.2 can. The average for the seven-year period, covering 55 separate reports and representing about 1,000 packing days, was 1.19 gallons per No.2 can, the minimum being 0.58 and the maximum 2.33 gallons. These studies indicated that "pea canneries are being satisfactorily operated with a water usage of two-thirds of a gallon per No.2 can, exclusive of cooling and boiler water."

One Ohio canner who operates a five-line plant states that his water consumption is about 20 gallons per case of No.2's, including cooling water. Another Ohio canner operating a one-line pea cannery uses 25 gallons per case of No.2's exclusive of cooling water. It appears that a one-line plant will have a somewhat higher per case consumption than a plant with more lines.

The Snider Packing Company, Albion, New York, used 336,000 gallons of water in packing 15,000 cases of No.2 cans of peas. This represents about 22.4 gallons per case.

Blancher wastes constitute about 10 percent of the total volume of wastes. Kimberley reports that a pea cannery producing a total volume of 200,000 gallons of waste per day produced an average of 17,500 gallons of blancher liquor.

The amount of stack or silo liquor can vary considerably, depending upon the water content of the stack. Wisconsin reports that about 1,650 gallons of liquor will drain each day during dry weather from a vine stack produced when 1,000 cases of peas are packed each day. A stack from 100 acres leaches from 30 to 40 thousand gallons of waste over a period of from 30 to 40 days.

Twenty-five gallons per case seems to be a fairly representative waste volume from a pea cannery. This is exclusive of cooling water and stack liquor.

Tomatoes

Tomato canneries packing whole tomatoes generally use much smaller amounts of water than pea or corn canneries. Data from a survey of such canneries in connection with the Ohio River Pollution Survey showed waste flows ranging from 1.5 to 40 gallons per case where reasonably accurate data on water consumption was available. Other studies have shown the following waste flows:

> 3 gal. per case - A Maryland cannery packing whole tomatoes and making pulp of the peels estimates its waste flow to be about 3 gallons per case of No.2 cans.
>
> 5 gal. per case - A Michigan cannery receiving 100 tons per day and packing whole tomatoes and puree was estimated to have waste flows of 210 to 230 per ton or slightly over 5 gallons per case.

7.5 gal. per case - Hommon, in studies at Amelia, Ohio in 1916 found .50 gallons of wastes produced per No.3 can of whole tomatoes (Net weight No.3 can 2 lbs.). This is equivalent to about 7.5 gallons per case of No.2 cans.

Information from a Michigan cannery indicates an average waste flow of 295 gallons per ton or about 7.5 gallons per case of No.2 cans. This cannery packs whole tomatoes and puree and recovers seeds. Some indication is shown of a decrease in volume of wastes per ton as the pack increased.

These figures indicate that about 7.5 gallons of waste per bushel of tomatoes or per case of No.2 cans is typical of a cannery packing whole tomatoes.

Tomato Products

Tomato products canning requires considerably larger amounts of water than whole tomato canning. Data from the Ohio River Pollution Survey on five plants canning only tomato products and buying water from municipal supplies indicate waste flows of from 30 to 90 gallons per case of No.2 cans. Other studies show the following:

38 to 95 gal. per bushel - The report on the Albion, N.Y. studies shows waste flows on the canning of tomato products varying between 69.5 and 94.0 with an average of 83.4 gallons per bushel corresponding to packs of 2,630 to 6,687 bushels of tomatoes. However, these same studies indicated that on a pack of 11,650 bushels the water consumption was about 587,000 gallons which corresponds to a bushel rate of only 38.6 gallons of water as waste.

50 to 100 gal. per bushel - One author states that volumes of waste from tomato products canning may vary from 50 to 100 gallons per bushel of tomatoes received.

80 gal. per bushel - Flow measurements during 1935 and 1936 at a tomato soup plant near Chicago showed average flows over 11-day periods of 78 and 92 gallons per bushel (40 bushels per ton) respectively, or an average of 80 gallons per bushel.

These figures indicate that 60 gallons of waste per bushel of tomatoes is typical of a tomato products plant. The variation indicated is from 30 to 100 gallons per bushel.

Character of Wastes

Wastes from the canning of cream style corn have a B.O.D. of about 620 p.p.m. and about 300 p.p.m. of suspended solids. The cleanup wastes are stronger than the continuous wastes during operations. Variations in strength from 50 to 200 percent of the above values are common. In canning cream style corn the starchy liquor washed from the cut kernels increases the pollution load considerably. The B.O.D. of the combined wastes from whole kernel corn canning is about 2,000 p.p.m. and the suspended solids about 1,250 p.p.m. Neither of these values includes the silage waste which is much stronger, having a B.O.D. of the order of 30,000 p.p.m.

Pea canning wastes have an average B.O.D. of about 1,700 p.p.m. and about 400 p.p.m. of suspended solids. Variations in B.O.D. of from 500 to over 7,000 have been noted in different plants. The strongest wastes are those from the blancher. The continuous blancher wastes contain a large amount of starch and have a B.O.D. of from 10,000 to 15,000 p.p.m. They are relatively low in suspended solids. The blancher is dumped once or twice a day and these wastes may be from two to three times as strong as the continuous discharge. The average figures for the combined cannery wastes do not include silage liquor which has a B.O.D. of from 50,000 to 75,000 p.p.m., from 1,500 to 2,000 p.p;m. of suspended solids and a pH of from 3 to 4.

Wastes from whole tomato canning are relatively high in B.O.D. although the volume is small. Analyses at a number of plants show an average of about 4,000 p.p.m. of B.O.D. with variations from 2,000 to 7,000 p.p.m. Wastes from the general cleanup at the end of the day's operations constitute from 20 to 30 percent of the total waste and are somewhat stronger than the wastes produced during operation. The wastes contain an average of about 2,000 p.p.m. of suspended solids but variations of from 600 p.p.m. to 4,000 p.p.m. have been found. The pH of the wastes is usually between 4 and 6, although when quite fresh the pH may be higher.

Tomato products canning wastes are more dilute than the wastes from whole tomato canning. The B.O.D. averages about 1,000 p.p.m. but may vary from about 200 to 2,000 p.p.m. Suspended solids are usually about 500 p.p.m. with comparable variations.

Sewered Population Equivalents

On the basis of the average flows and analyses from various canneries, the sewered population equivalents shown on Table Cn-2 have been determined.

Table Cn-2 Sewered Population Equivalent of Cannery Wastes Based on B.O.D. and Suspended Solids

Product	Sewered Population Equivalent per 100 cases of No.2 Cans per Day	
	B.O.D. (1)	Suspended Solids (1)
Corn (Cream Style)	75	30
Corn (Whole Kernel)	250	130
Peas	210	40
Whole Tomatoes	150	60
Tomato Products	350	150

(1) Based on 0.167 lbs. of 5-day, 20° C. B.O.D. and 0.20 lbs. of suspended solids per day.

Pollution Effects

The polluting effects of cannery wastes are due to their oxygen depleting characteristics. They contain no harmful bacteria nor toxic substances. In general, they are colored and this effect may make the receiving water unsightly. The solid material is light and does not settle readily but has a tendency to float and form a scum.

Remedial Measures

Within the Cannery

A number of steps can be taken within a cannery which will reduce the polluting effects of its wastes at relatively small cost. These steps, which are often quite attractive in reducing cost of subsequent treatment, include:

(a) Removal of all gross solids such as husks, cobs, peelings, culls, trimmings, etc., before they can enter the sewers. These should be disposed of separately, either by returning them to farms as fertilizer or animal food or in some other manner which will prevent their entrance into natural watercourses.

(b) Proper adjustment of filling machines to reduce spills during this operation. Unavoidable spills of small amounts of material can be disposed of with garbage.

(c) Separate disposal of any stack or silage liquor in some manner which will prevent its entrance into natural watercourses.

(d) Fine screening of all polluted liquid wastes on a 40 to 60 mesh rotating or vibrating screen equipped to prevent clogging of the screen.

Effective treatment following screening has been provided by lagooning, chemical precipitation, trickling filters, intermittent sand filters, and by treatment in municipal plants with domestic sewage. Plain sedimentation without the aid of chemicals removes little of the B.O.D. of most cannery wastes although some experiments have shown it to be effective with tomato wastes.

Lagooning

Lagooning may be satisfactory at rural canneries where ample space is available, the operating season short, and the creation of an odor nuisance of no great importance. Relatively little purification takes place in the lagoon but if it is large enough to hold an entire season's flow or a major part thereof, the wastes can be discharged in small amounts over long periods of time when temperatures are low and stream flows high and thus avoid polluting the receiving stream to any great extent.

The lagoon should be shallow and the dikes or walls well built and impervious in order to prevent washouts or other accidental discharges. Diversion ditches may be necessary to prevent the entrance of surface water. Seepage into the soil and evaporation may dispose of a part of the waste but, in the Ohio Basin and,in general, throughout the eastern half of the United States, evaporation is not very effective. The lagoon should be emptied and cleaned before each operating season. If this is not done, the deposited solids will soon clog the soil openings and prevent seepage. The effluent from the lagoon is often disposed of by broad irrigation where suitable tracts of land for this purpose are available.

The principal disadvantages of lagoons are the odor nuisances they create and the serious consequences of accidental discharges due to structural failure or bad operation. Careful operation is as necessary with a lagoon as with any treatment plant, but unfortunately they seldom receive such operation. A preliminary edition of one of these guides suggested that odor nuisances can be reduced or entirely eliminated by adding sodium nitrate to the lagoon. Such treatment has been used on several occasions to eliminate odors due to various types of wastes and experimental studies by the National Canners Association of its application to lagooned cannery wastes indicated that the addition of enough nitrates to satisfy 50 percent or possibly less of the five-day B.O.D. of the wastes not only prevented odors but reduced the B.O.D. by from 66 to 76 percent. Results of a trial at an Illinois cannery should be available soon.

Chemical Treatment

Chemical precipitation has been extensively studied and widely used as a method of treating cannery wastes of various kinds. This method of treatment is particularly well adapted to canneries with short operating seasons because of its low first cost. The primary consideration has been found to consist in raising the pH of the waste to at least 10. Lime is used to do this since it is the cheapest chemical for the purpose. The effectiveness of the treatment is greatly increased by the addition of other precipitants such as various iron salts, alum, and zinc chloride. In general, the fill and draw plan of operatio has been found preferable to the continuous flow plan for moderate sized installations.

Corn Canning Wastes are considered harder to treat with chemical precipitation than tomato or pea canning wastes. Table Cn-3 shows the results of experimental treatment at Canal Winchester using alum and soda ash at rates of 20 and 8 g.p.g. respectively during the first run and 15 and 5 g.p.g. during the second run.

Table Cn-3 Chemical Precipitation Results, Straight Factory Run Wastes

Determination	First Run			Second Run		
	Influent	Effluent	% Removed	Influent	Effluent	% Removed
	Results in parts per million					
5-Day B.O.D.	797	525	34.2	582	450	22.7
Oxygen consumed	930	486	47.8	318	289	11.9
Organic Nitrogen	15	6.7	55.2	11.8	6.7	43.2
Solids:						
Total suspended	273	100	63.3	311	212	31.9
Vol. suspended	256	84	67.2	182	80	56.2

These results show relatively low B.O.D. removals.

Experiments with full sized treatment units at the Cedarburg, Wisconsin cannery during the corn pack showed that much better results can be obtained. The coagulants used with lime included ferrous sulfate, ferric sulfate, ferric chloride, zinc chloride, alum, and bentonite. Of these, ferrous sulfate, and zinc chloride gave the best B.O.D. removals. Table Cn-4 shows the results of these experiments.

"Methods of Treating Cannery Wastes", by Warrick, et al., states, "Experience on both small and large scale operation has shown that if the ferrous sulfate is added in a single dose, the floc produced is small and slow in settling and the supernatant liquid remains milky. Further additions of ferrous sulfate are then necessary to produce the desired water-clear supernatant liquid. For example, the addition of 5 pounds of ferrous sulfate followed by four successive 1-pound additions, making a total of 9 pounds, produced a clear supernatant liquid. When, however, 9 pounds of ferrous sulfate was added in a single dose, the supernatant remained cloudy and further addition was required for clarification.

"In regard to this phenomenon, the following theory is advanced: When an amount of iron previously shown to be sufficient

Table Cn-4 Results Obtained by the Chemical Treatment of Corn Waste, in Quantities (Batches) of 11,350 Gallons

Lime added per 1000 gals.	Chemical added per 1000 gals.	pH raw	pH treated	5-day B.O.D.			Oxygen consumed			Raw				Treated		Supernatant
				Raw	Treated	Reduction	Raw	Treated	Reduction	Total solids	Total volatile solids	Suspended solids	Volatile suspended solids	Total solids	Total volatile solids	
Lbs.	Lbs.			p.p.m.	p.p.m.	Percent	p.p.m.	p.p.m.	Percent	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	
	Zinc chloride															
6	0.75			985	136	86	800	175	78	2,394	1,400	316	274	2,212	186	Clear
7	2.25	7.6	11.9	740	114	85	1,460	646	56	2,340	1,488	188	164	2,078	602	Milky
6	2.55	7.9	11.8	930	246	74	1,610	720	55	2,648	1,730	218	206	2,042	640	Clear
6	3.0			1,260	360	79	2,000	825	59	3,120	2,266	512	498	2,360	868	do
6	2.0	5.9	11.0	1,345	195	85	825	415	50							Slightly cloudy
6	2.0	6.0	10.9	1,190	385	68	1,930	850	56							Cloudy
6	2.0	6.5	10.9	1,350	465	66	2,090	1,475	29							do
6	2.0			1,050	513	51	875	300	66	2,326	1,430	180	140	1,872	792	Clear
6	2.5			1,120	355	68	1,000	500	50	2,498	1,740	214	210	2,288	956	Cloudy
6	3.25	6.9	12.4	1,460	410	72										do
6	3.25			1,835	510	72^a										Cloudy
7	6.8			2,060	515	75^a										Clear
6	4.6			1,750	430	75^a										do
	Ferrous sulfate															
10	8.4			1,760	480	73	1,150	620	47	3,086	2,278	432	432	2,752	936	do
10	10.0	7.8	12.1	1,490	300	80	2,100	800	62	3,248	2,448	546	546	2,582	580	do
10	8.4	8.0	12.5	1,530	310	80	1,950	666	66	3,068	2,256	800	800	2,698	680	do
10	8.0		12.5	1,860	368	81	2,150	833	61	3,298	2,434			2,752	780	Slightly cloudy
8.8	3.8	7.4	12.0	1,270	236	81	600	465	23	2,320	1,478	502	500	2,652	740	Clear
6.6	3.8	7.3	12.3	1,160	245	79	950	670	30	2,700	1,828	438	436	1,960	640	do
8	8.0		13.4	2,250	370	82	2,100	433	79	3,696	2,796	878	868	2,380	680	do
6	4.8	7.8	11.5	2,150	555	74	2,050	833	59	3,698	2,752	1,164	1,144	2,486	946	Cloudy
8	8.0	7.5	13.3	2,160	513	76	2,600	900	65	4,160	3,114	936	926	2,834	976	Slightly cloudy
6	6.5			2,400	570	80	2,300	933	59	3,782	2,856	1,164	1,164	2,676	1,142	do
8.8	8.0			1,770	355	80										do
8.8	8.0			2,040	460	77										do
8.8	8.8			2,020	510	75				4,852	3,804	1,146	1,134	3,348	1,178	Clear
6	4.8			2,115	422	80^a										Cloudy
8	8			3,480	595	83^a										Slightly cloudy
8.8	8			2,020	358	82^a										do
8.8	8.8			2,850	1,005	65^a										Clear
8.8	6.1			1,390	435	69^a										do
10	9.5			2,250	700	69^a										Cloudy

(^{a}) Results obtained by supplemented dilution water.

to produce in stage precipitation a water-white supernatant liquid is added to the limed waste in a single dose, it fails to clarify because the surface of the floc becomes coated with colloidal starch. The ability of the floc to adsorb additional colloidal starch is thus destroyed. When, however, the same amount of iron is slowly added, fresh surfaces are built up on the flocs, which are then able to adsorb additional amounts of colloidal starch. The adsorption capacity of the surface of a floc is limited and must be renewed by the addition of more of the floc-forming material.

"Numerous large-tank treatments conclusively showed that when the lime is added slowly over a period of five to ten minutes while the mixing agitator is revolving, the resultant floc, when mixed with the second precipitant, gives a more rapid settling final floc, leaving a clear supernatant. Physical observations indicated that if the lime is added at a rapid rate or while the tank is filling, the supernatant is cloudy and the floc slow in settling. After the slow addition of lime, followed by stage addition of the second precipitant, the mixing agitator should not be allowed to revolve longer than one minute after the last chemical addition". These results may explain some of the unsatisfactory results experienced elsewhere in chemical treatment of corn wastes.

The following conclusions were reached in the above mentioned bulletin: "An oxygen demand reduction of approximately 70 percent was obtained on screened corn waste by the addition of approximately 9 pounds of lime and 8 pounds of ferrous sulfate or 6 pounds of lime and 2 to 6 pounds of zinc chloride per 1,000 gallons of waste when the described procedure is used. A dosage of 8 pounds of lime and 3 pounds of ferric chloride per 1,000 gallons of screened waste reduced the oxygen demand approximately 57 percent. A dosage of 8 pounds of lime and 7 pounds of ferric sulfate per 1,000 gallons of screened waste reduced the oxygen demand 46 percent."

Pea Cannery Wastes are treated by chemical precipitation at many plants. Studies by the Wisconsin State Board of Health in 1926 indicated that reductions in B.O.D. of 50 to 75 percent could be obtained by the application of 7¼ pounds of lime and 3¼ pounds of ferrous sulfate per 1,000 gallons of waste. Later experiments showed lower efficiencies as shown in Table Cn-5. These experiments indicated that the best coagulant with lime was zinc chloride. Later results on plant scale operations showed much lower reductions (24 percent). Ineffective mixing and improper control of chemical feed were stated to be the causes of the difference.

Table Cn-5, Results Obtained by the Treatment of Pea Waste with Various Chemicals, in Quantities of 100 Gallons.

Lime added per 1,000 gals.	Chemical added per 1,000 gals.	pH	5 - day B. O. D.				Floc	Supernatant
			Raw	Treated	Actual reduction	Average reduction		
Lbs.	Lbs.		p.p.m.	p.p.m.	Percent	Percent		
	Ferrous sulfate							
7.0	2.9	10.6	1,500	460	69	-	Good	Clear
7.0	3.0	-	2,370	1,330	44	-	do	Slightly cloudy
7.0(a)	3.0	-	3,130	1,780	43	-	do	Clear
7.0(b)	3.0	-	590	400	32	47	do	do
	Alum							
7.0	2.9	10.6	1,500	400	41	-	do	do
7.0	3.0	9.7	1,880	880	54	-	do	Fairly clear
7.0	3.0	-	3,230	2,070	36	-	do	Clear
7.0	5.5	9.6	1,030	830	19	45	do	do
	Ferric chloride							
7.0	3.0	-	2,470	1,510	39	-	do	do
5.5	1.25	9.8	1,270	720	43	-	do	do
8.25	3.75	9.8	1,270	830	35	39	do	do
	Ferric sulfate							
7.0	3.0	-	2,130	1,780	16	-	do	do
5.0	1.0	9.8	1,350	680	50	-	Fair	Cloudy
5.0	2.0	9.2	1,350	1,070	21	33	do	do
	Zinc chloride							
6.0	2.0	11.7	1,640	385	77	-	Good	Clear
6.0	4.0	11.7	1,730	470	73	75	do	do

(a) 1 pound of carbon added prior to lime addition.
(b) 0.35 pound of carbon added prior to lime addition.

Tomato Wastes have been found to be quite amenable to chemical treatment. A one-day test at an Ohio tomato cannery gave the following results:

Waste: Wash water only, 7,200 g.p.d.
Chemicals: Ferrous sulphate 840 p.p.m.
Lime - 280 p.p.m. Orifice box feed.
Mixing: 23 minutes, mechanical agitator.
Sedimentation: 2.3 hours. Sludge removed periodically and hauled to fields by truck.
Ponding: 6 ponds 15-days detention. Cooling and condenser water (5,000 g.p.d.) added and total flow passes through series of ditches to creek.
Analyses: (See Table Cn-3)

	Raw	Settled	Ditch
Susp. Solids p.p.m.	1910	562	41
B.O.D. 5-day "	6436	3988	265

Remarks: Ponding alone proved unsuccessful. Dry chemical feed and sludge removal mechanism recommended.

A Pennsylvania tomato products plant has a chemical precipitation plant which has been in service since 1930.

Wastes: All wastes from plant 375,000 g.p.d.
Fine Screens: North rotating screen - 40 mesh.
Chemicals: Sodium Aluminate 50 p.p.m.
Lime 640 p.p.m.
Mixing: 11 minutes, baffled chamber.
Sedimentation: 6½ hours. Sludge pumped from hoppers on first tanks to sludge field.
Analyses: (Ave. 2 days)

	Screened	Settled	% Reduc.
Sett. Sol. cc./l	28	2.6	91
B.O.D. 5-day p.p.m.	300	165	45

An Ohio tomato products plant built chemical precipitation waste treatment works in 1937. The details of this plant and the results of a test (by State of Ohio) on September 7 and 8, 1939 are as follows:

Design Capacity - 1,200,000 gallons per 20 hours (1,000 gal. per minute). Sept. 7 and 8 - 800,000 g.p.d. (20,000 bu. per day tomatoes).

Pumps - 4,800 gal. wet well. Two 500 g.p.m. centrifugal pumps, float controlled.

Screens - Two North fine (50 meshes per inch) rotating screens 6 ft. diameter by 10 ft. long. Screenings - to hopper, hoist and trucks. Screen spray - 100 g.p.m. recirculating pump.

Chemicals - Lime feed machine - capacity 50 to 2,400 lbs. per 24 hours. Ferric chloride feed machine - capacity 50 to 750 lbs. per 24 hours. Control by float switches on pumps. Point of application - wet well. Sept. 7 and 8 - Lime (hydrated) dose 24 lbs. or 360 p.p.m. Ferric chloride dose - 460 lbs. or 69 p.p.m.

Flocculation - 8 ft. x 33 ft. x 10 ft. 6 in. water depth, 20 min. detention. Mechanical agitation - three sets of paddles (parallel to shaft on drum) on single horizontal shaft. 6 ft. diameter, 10 ft. long. Peripheral speed 2 ft. per sec.

Sedimentation - Two tanks - 16 ft. x 63 ft. 6 in. x 7 ft. 9 in. water depth (flat bottom). Capacity - 115,000 gal. Detention - 1.9 hours. Velocity - 0.6 ft. per min. Sludge hoppers, two at inlet - 6 ft. 6 in. x 8 ft. x 2 ft. 6 in. deep. Capacity 130 cu. ft. each. Sludge removal continuous, pumped to screenings hopper for truck disposal (on land).

Analyses - Sept. 7	Raw	Settled	% Red.
Susp. sol. p.p.m.	388	9	98
Total N. "	19	14	76
B.O.D. (5-day 20°C.)	830	392	53
Sewered Pop. Equiv. (Based on B.O.D.)	34,600	16,300	53

Experiments in Wisconsin indicated that plain sedimentation may be effective on tomato wastes. The wastes used in the experiments were rather weak (B.O.D. of screened wastes averaged 570 p.p.m.). Alum, sodium aluminate, zinc chloride, ferric chloride, ferrous sulfate, bentonite, and otaylite were used with lime. Alum showed the most favorable results. Plain sedimentation reduced the B.O.D. by 37 percent. Four pounds of lime and one pound of alum per 1,000 gallons of waste increased the efficiency to about 54 percent.

Eldridge found that treatment of tomato wastes with lime alone was as effective as treatment with lime and ferric chloride. The optimum amounts of lime were found to be from 800 to 900 p.p.m. (about 6.7 to 7.5 pounds per 1,000 gallons) when using fill and draw tanks with four-hour sedimentation period.

A fourteen-hour sedimentation period showed worse results because of gas formation in the sludge. When using a 2.5 hour detention period with a flowing-through tank the optimum lime dosage was about 1,000 p.p.m. (about 8.3 pounds per 1,000 gallons). Reductions in B.O.D. were generally from 40 to 50 percent.

Trickling Filters

Trickling filters have shown satisfactory results in the treatment of corn, pea, and tomato wastes. The fact that they require a considerable amount of time after the beginning of operation to attain full efficiency limits their usefulness. In general, the data indicate that after a suitable period of seeding trickling filter plants will accomplish overall reductions of 50 to 85 percent in the B.O.D. of the screened wastes. Different experiments have not been in complete agreement on the allowable B.O.D. load per unit of filter area or volume. Various methods of pretreatment also have been used.

Corn canning wastes were treated on an experimental scale on a trickling filter at Canal Winchester. The media was $\frac{1}{4}$" - 2" limestone and the filter was 6 ft. deep. The only pretreatment was screening. The filter was dosed at a rate of 2,400,000 gallons per acre per day. After a suitable period of ripening, the filter reduced the B.O.D. of the raw screened wastes from 600 p.p.m. to 140 p.p.m. Pennsylvania authorities report poor results with trickling filters on corn wastes. Both high rate and conventional types are in operation. The results, however, are not conclusive. Various changes have been suggested which may overcome the difficulties.

Tomato products wastes were treated experimentally at Bowling Green, Ohio. Some of the conclusions reached as a result of the study were as follows:

1. There was practically no lag between the time the trickling filter treating tomato wastes was placed in operation and the time that typical purification efficiencies were obtained.

2. Typical trickling filter efficiencies with tomato wastes (with about 300 p.p.m. 5-day B.O.D.) were as follows:

Million gallons per acre per day	B.O.D. removal percent
2.5	76
1.5	85
0.75	85
1.5*	78

---

* Equal parts sewage and tomato wastes.

In 1916 an experimental whole tomato waste treatment plant was operated at the Colter Canning Company, Amelia, Ohio, by the U. S. Public Health Service. The processes involved were sedimentation followed by filtration through cinder and sand filters in series. The details of this plant and test results after an initial operating period were as follows:

Sedimentation - Imhoff tank.

Settling compartment - Adequate to be used as storage for complete equalization of flow throughout the 24 hours, or with a capacity equal to the maximum daily flow minus total gallons applied to filters during working day.

Sludge compartment - (recommended) 1.2 cu.ft. per 1,000 No.3 cans (0.7 cu.ft. per 1,000 No.2 cans) per season.

Cinder Filters - 4 feet deep (plus underdrain). Average rate 72,000 gallons per acre per day (75,000 g.a.d. recommended).

Sand Filters - 4½ feet deep (plus underdrains). Average rate 72,000 gallons per acre per day (75,000 g.a.d. recommended).

Sludge Bed - Standard design 1.2 sq. ft. per 1,000 No.3 cans (0.7 sq.ft. per 1,000 No.2 cans) per season.

Analyses -	*B.O.D. 5-days, 20°C.*
Raw	4400 p.p.m.
Settled	5000 "
Cinder filter effluent	1400 "
Sand filter effluent	Stable - over 96 hours.

Studies at Greenwood, Indiana during 1936 and 1937 indicated the practicability of high-rate trickling filters. Table Cn-6 shows operating data and average B.O.D. reductions.

Table Cn-6 Results of Operations Using Chemical Precipitation and One-Hour Batch Settling Followed by High Rate Trickling Filters.

Operating Data	1936	1937
Rate return to filter	1-1	2-1
Filter rate (1)	30	30
Type waste	Tomato	Mixed Vegetables (2)
Chemical dose per 1,000 gal.	5 lbs. lime, 0.75 lbs.copperas	5.3 lbs. lime, 1.8 lbs. copperas
B.O.D. - p.p.m.		
Raw screened wastes	915	1,191
Primary Effluent	599	678
Filter Effluent	277	489
Secondary Effluent	230	370
Percent Reduction	75	69

(1) Million gallons per acre per day.
(2) Tomato, corn, lima bean, green bean, carrots and mixed vegetables.

Among the conclusions reached were:

(1) Lime and copperas are the most efficient coagulants available at the present time. For the best results the pH should be about 8.4. Larger amounts of coagulants than those shown above gave considerably better results. Thorough mixing of the coagulants is necessary.

(2) Air should enter the filter both at the top and bottom. A blower is necessary to force the air up through the bottom. At least two weeks time is required to build up the growth on the media.

(3) Small sized filter media (1"-2½") cannot be used in high rate filters on cannery wastes. The filter equipped with media ranging from 2½"-4" did not clog when being operated at a high rate.

(4) The increased efficiency of the high rate filter when operating at a return ratio of three to one rather than a return ratio of one to one does not apparently justify the additional cost.

(5) Sludge may be at least partially dried on ordinary sludge drying beds. After about six days, the pasty sludge can be removed by shoveling. A large percent of the sludge, especially that from the green bean, lima bean, beet, carrot, and mixed vegetable waste was due to the addition of the copperas and lime.

Studies in Wisconsin using a high rate stone filter 8 feet deep with 2½"-3" media and a tile filter 7.5 feet deep treating screened corn and tomato wastes showed the results shown on Table Cn-7.

Table Cn-7 Results Obtained by High Rate Trickling Filter Treatment of Corn and Tomato Wastes.

Item	Unit	Corn Waste		Tomato Waste	
		Tile Filter	Stone Filter	Tile Filter	Stone Filter
Dosage	m.g.a.d.	26.7	21.4	24.4	12.8
Recirculation	percent	70	69	none	none
Settling tank detention	minutes	26	47	28.0	78.5
Sampling period	hours	3.5	3.5	6	6
5-day B.O.D.					
Raw	p.p.m.	1,660	1,660	850	850
Filtered	"	980	730	740	370
Settled	"	760	510	530	370
Total B.O.D. reduction					
Filtered	percent	41	56	12	56
Settled	"	54	69	38	56

Data obtained from these studies are too limited to permit accurate generalization.

Pea wastes were treated on a conventional trickling filter at Albion, N.Y. in 1928 and 1929. The filter was 8 feet deep, the media 1½"-2-3/4" crushed limestone. A 20-mesh screen was the only pretreatment. The first three columns of Table Cn-8 summarize the results of the experiments. The last column shows the results of tests on the filter installed as results of the experiments. The depth of the filter is unknown. It was built in an abandoned quarry and is thought to vary between 8 and 20 feet in depth.

Table Cn-8 Treatment of Pea Cannery Wastes on Trickling Filters at Albion, N.Y.

Dosage	m.g.a.d.	1.96	0.98	0.58	1.82
5-day B.O.D.					
Screened	p.p.m.	713	1,157	1,715	1,880
Filtered	"	453	509	400	703
Reduction	percent	36	52	79	65

The high rate filters used in the Wisconsin studies of corn and tomato wastes were also used in treating wastes from pea canning. After 15 days conditioning, the results shown on Table Cn-9 were obtained.

Table Cn-9 Results Obtained by High Rate Trickling Filter Treatment of Pea Canning Waste.

		Tile Filter			Stone Filter		
Date		7-12	7-15	7-16	7-12	7-15	7-16
Dosage	m.g.a.d.	20.0	20.0	20.0	20.0	20.0	20.0
Recirculation	percent	63	63	63	63	63	63
Settling tank detention	min.	34	34	34	50	50	50
Sampling period	hrs.	7.5	8	10	7.5	8	10
5-day B.O.D.							
Raw	p.p.m.	660	1670	1690	660	1670	1690
Filtered	"	530	1140	1170	410	860	700
Settled	"	470	1100	610	480	650	1400
Total B.O.D. reduction							
Filtered	percent	19	32	31	37	49	59
Settled	"	29	34	64	28	61	23

Intermittent Sand Filters

Relatively little information is available on the efficiency or suitability of this device for treating cannery wastes. Studies at Canal Winchester on wastes from corn, succotash and lima bean canning showed good results. The filters consisted of 30" of sand (effective size 0.27 mm., uniformity coefficient 2.3) over 6" of torpedo sand and 6" of graded gravel. Table Cn-10 shows the results of the experiment.

Table Cn-10 Results of Intermittent Sand Filtration of Corn, Succotash, and Lima Bean Wastes.

Date	Screened Wastes		Effluent from Sand Filters			
	B.O.D.	S. S.	B.O.D.	S.S.	B.O.D.	S.S.
Dosage Rate			75,000 gallons per acre per day		100,000 gallons per acre per day	
9/3/26	-	-	112	20	140	10
9/10/26	533	228	28	32	27	40
9/13/26	344	344	59	34	54	26
9/17/26	581	267	31	40	53	60
9/21/26	455	290	22	80	16	40
10/1/26	200	383	23	4	37	4
10/7/26	175	460	0	40	0	52

Siebert says: "Wastes from a Pennsylvania cannery packing whole kernel corn have been treated with promising success in a plant providing fine screening, one-hour plain sedimentation, intermittent sand filtration at a rate of about 100,000 gallons per acre day and drying of settled solids on a sludge bed having an area 10 percent of the intermittent sand filters. An efficiency of 85 percent in reduction of B.O.D. (raw B.O.D. average 4,900 p.p.m.) was measured in this plant but the two filters finally became matted with starch jelly which would not dry rapidly enough for removal. One additional filter (50 percent increase in present filter area) would probably make the treatment plant sufficiently flexible to operate successfully over the entire 5 or 6 weeks of the corn canning season but it is doubtful if treatment of this type would be suitable for strong full-line cannery wastes over a long season because of cumulative clogging of the filters without sufficient rest periods for decomposition of the clogging materials."

Treatment with Municipal Sewage

From the standpoint of the cannery, this is the simplest method of waste disposal. It may also be the most economical method since the incremental cost necessary to provide treatment in the municipal treatment plant may be less than the cost of building and operating an independent treatment plant for the cannery waste. From the standpoint of an agency administering pollution abatement laws, this method is desirable since it centralizes responsibility for proper operation of treatment works

Since the methods of treating cannery wastes are similar to those for sewage treatment, it should be possible, at least theoretically, to treat a mixture of cannery wastes and sewage in almost any proportion if the plant is properly designed and operated.

The municipal treatment plant at Celina, Ohio (population 4,841) treats cannery wastes with a population equivalent of about 18,000 in addition to wastes from a large creamery. The plant is of the activated sludge type with chemical pretreatment at the municipal plant. The wastes are screened at the cannery and chemical dosage is regulated by the treatment plant chemist on the basis of daily reports from the cannery as to the amounts of various products to be canned. These products include peas, beans, beets, tomatoes, hominy, and spaghetti. The coagulants used are lime and either ferrous or ferric sulfate. Table Cn-11 shows the results obtained during the last six months of 1940, during which time the cannery operated all but 31 days.

Table Cn-11 Monthly Average Results of Treatment of Sewage, Cannery Waste and Milk Wastes at Celina, Ohio Municipal Treatment Plant, 1940.

Month	Waste Flow m.g.d.	Biochemical Oxygen Demand			Suspended Solids		
		Raw	Treated	Percent Red.	Raw	Treated	Percent Red.
		Results in parts per million					
July	.408	1500	23	98.5	352	13	96.3
Aug.	.480	1037	58	94.6	591	32	94.6
Sept.	.438	865	37.2	95.7	445	67	85.0
Oct.	.399	840	20.2	97.6	510	22	95.7
Nov.	.370	790	21.2	97.3	550	21	96.2
Dec.	.420	463	38.2	91.7	402	56	86.1

The municipal treatment plant at Yakima, Washington, providing primary treatment treats cannery wastes equivalent in suspended solids to 165 percent of the domestic sewage load. No operating difficulties are reported and removals of 55.3 percent of the suspended solids and 43.8 percent of the B.O.D. are obtained when treating the combined sewage and industrial waste.

In addition to these, there are many other municipal treatment plants successfully treating cannery wastes which place much heavier B.O.D. loadings on the plant than the ordinary municipal sewage. Careful operation, including coordination of treatment plant operation with cannery operation, and adequate design are necessary if satisfactory results are to be obtained. Chemical treatment, either at the cannery or at the municipal plant, is usually desirable if biological treatment is provided.

Studies of the efficiencies of four Wisconsin sewage treatment plants treating cannery wastes which had been pre-treated by chemical precipitation at the cannery showed that both trickling filters and activated sludge plants can treat these wastes effectively if the B.O.D. load is not too heavy. All of the plants were overloaded during peak canning operations and plant efficiencies were reduced by these overloads but all of the plants recovered within a short time after the cessation of canning. The report on these studies concluded:

"Municipal treatment plants of the trickling filter type should be of sufficient size to provide a minimum of 80 cubic feet of filter media per pound of 5-day B.O.D. per 24 hours to maintain a high degree of efficiency during peak cannery loads. A finishing sand filter provides substantial additional treatment. Activated sludge plants receiving sufficient cannery waste to produce a sludge index in excess of 200 may be expected to cause bulking and other operating difficulties."

Costs

The cost of cannery waste treatment plants has been estimated by Warrick, etc. al., as follows:

Type of Treatment	Size Cannery	Capital Cost	Daily Cost	Cost per Case
	Cases/ day			
Chemical Precipitation	2,000	$3,000	19.10	$ 0.01
" "	5,000	5,000	33.85	0.007
Trickling Filters	2,000	13,000	29.80	0.015
" "	5,000	16,000	37.45	0.0075

These estimates are based on assumptions of 25 gallons of waste per case, a treatment plant life of 20 years, an annual operating season of 50 days and interest at 5 percent. The trickling filter plants do not include chemical precipitation. The daily costs include allowances for depreciation and interest.

The Indiana State Board of Health estimated that a plant providing chemical treatment and high rate filters for a cannery waste flow of 100,000 gallons per day would cost about $8,000. Operation and maintenance were estimated at $19.00 per day, including labor, chemicals, power, and maintenance.

Nitrate treatment to lagooned pea wastes was estimated by Sanborn to cost about $0.004 per case. This is based on a B.O.D. of 1,500 p.p.m. The cost of lagoons varies so much with local conditions that no general figure can be given.

Treatment Plant Design

Regardless of how the wastes are disposed of, there is general agreement that fine screening is essential. Forty-mesh screens have proved satisfactory, although coarser screens (20-28 mesh) are sometimes used. They may be either of the rotating or vibrating type, should be equipped with a continuous strong water spray (about 40-60 p.s.i. pressure). A steam cleansing once a day is useful to prevent slime growths. At least one square foot of screen area should be provided for each 200 gallons of waste per hour. A bar rack or coarse mesh bucket screen is desirable ahead of the fine screen to intercept the coarsest material and to prevent damage to the screen.

Fill and draw chemical precipitation tanks should provide at least one hour of quiescent sedimentation. Addition of chemicals and mixing require an additional 15 to 20 minutes. In continuous flow plants the coagulation basin should provide about 15 minutes detention and the sedimentation basin about 90 minutes detention. Hopper bottom tanks are generally used because of their lower first cost than tanks equipped for continuous sludge removal. The hoppers should have a slope of not less than 45 degrees. Round tanks are preferable to square ones, particularly for fill and draw operation, since they facilitate thorough mixing and sludge removal.

The available data on trickling filter performance with cannery wastes are not conclusive enough to permit any positive general statements regarding permissible B.O.D. loadings. Various experiments indicate that the strength of the applied waste, the type of pretreatment, the pH of the applied waste, the size of the filter media and the ventilation of the filter have important effects on the efficiency of trickling filters. Stone of 2½" minimum size has been found most satisfactory. B.O.D. removals in secondary settling tanks seem to be higher in cannery waste treatment plants than in sewage treatment plants. Efficiencies comparable to those of trickling filters treating domestic sewage probably require about the same volumes of filter media but much higher loadings can be applied at a sacrifice of efficiency.

Sludge beds for drying sludge from the chemical precipitation tanks dries readily in a week or less. About 3,000 square feet of drying beds are required per 100,000 gallons of waste per day. The beds should be about 12" deep with 6" of sand on 6" of graded gravel. Underdrains should be provided as in any sludge drying bed.

Bibliography

(1) Anon., Complete Course in Canning, 5th Edition. The Canning Trade, Baltimore, Md. (1936).

(2) Carpenter, W. T., Sodium Nitrate Used to Control Nuisance Water Works and Sewerage, 79, 175 (1932).

(3) Eldridge, E. F., Report on Sanitary Engineering Projects for 1937 Engineering Experiment Station Bulletin No.78 (1938) Michigan Engineering Experiment Station, East Lansing, Michigan. Also Report on Sanitary Engineering Projects for 1938 Engineering Experiment Station Bulletin No. 83 (1938) Michigan Engineering Experiment Station, East Lansing, Mich.

(4) Eldridge, E. F., Industrial Waste Treatment Processes and Plant Design. Engineering Experiment Station Bulletin No. 82 (1938), Michigan Engineering Experiment Station, East Lansing, Mich.

(5) Fales, A. L., Treatment of Industrial Wastes from Paper Mills and Tannery on Neponset River. Industrial and Engineering Chemistry, 21, 216 (1929).

(6) Gregory, T. R., and Kimball, J. H., Cannery Waste at Palo Alto. Sewage Works Journal, 9, 607 (1937).

(7) Hommon, H. B., The Purification of Tomato Canning Factory Waste. U. S. Public Health Service Bulletin, No. 118(1921).

(8) Indiana State Board of Health, Operation of Experimental Cannery Waste Treatment Plant. Unpublished Report, 1937 (see also Food Industries, August, 1937, p. 430).

(9) Kimball, J. H. and May, H. L., Developments in Cannery Waste Studies at Palo Alto Sewage Works Journal 13, 731 (1941).

(10) Kimberly, A. E., Progress Report on Cannery Waste Treatment Studies, Ohio State Health Department, Columbus, Ohio, 1927.

(11) Kimberly, A. E., Information from files.

(12) LeBosquet, M. Jr., Unpublished data, 1931.

(13) LeBosquet, M. Jr., Removing Pollution from Streams by Chemical Precipitation. Paper at Pennsylvania Water Works Assn., 1930.

(14) Lutz, H. C., Cannery Waste Treatment in Pennsylvania. Paper at Pennsylvania Sewage Works Assn., June 1939.

(15) Maryland Water and Sewerage Assn., Proceedings, Third Annual Conference (1929).

(16) Mohlman, F. W. Unpublished data, Sanitary District of Chicago (1935-38).

(17) New York State Department of Health. The Treatment of Canning Waste (1930).

(18) Ohio State Health Department, Information from files.

(19) Ohio River Pollution Survey, U. S. Public Health Service (1939-41). Information from files.

(20) Ryan, W. A., Effect of Cannery Wastes on Operation of Sewage Treatment Plants. Sewage Works Journal 12, 99 (1940).

(21) Sanborn, N. H., Nitrate Treatment of Cannery Waste. The Canner, March 22, 1941.

(22) Siebert, C. L., A Digest of Industrial Waste Treatment April, 1940, (mimeo.).

(23) Warrick, L. F., McKee, F. J., Wirth, H. E., and Sanborn, N. H., Methods of Treating Cannery Waste. National Canners Ass'n. Research Laboratory Bulletin No.28-L, Washington, D.C., 1939.

(24) Wisconsin State Board of Health, Stream Pollution in Wisconsin, Madison, Wis., 1927.

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

I-2
Rev.8-39

CANNERY WASTES (Not an Actual Cannery)

Plant West Liberty Canners State Ohio Ref.No. Mi Ma-130,8

City West Liberty County Logan Main Watershed Miami River

Address West Liberty, Ohio Sub-watershed Mad River

Informant J. L. Doe Title Supt. & Owner Principal Product Whole Tomatoes

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	60	30	100-110
Maximum	72	10 to 12	110

Seasonal variation Operate from Aug. 10-15 to Oct. 1-10 or Killing Frost

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	Municipal	3,000	8,000	Boiler Water
Industrial	Well	12,000	12,000	Softened
Cooling	Total	15,000	20,000	

PRODUCTS CANNED:- Ave. 60,000 Cases No.2 Cans Whole Tomatoes per Year Including 4,000 to 5,000 Cases Puree and Juice

Normal production, height of season 2,000 Cases per day

WASTES:- Quantity 15,000 How estimated Water Bills & Pump Capacity

Washing 15,000

Other

Disposal other than water carried Skins, Cores etc. Hauled to Farm Land

Possible spills Filler may Overflow Occasionally

Segregation of Strong Wastes None except as above

Difficulties None for Extension of Disposal on Farm Land

Treatment Fixed Bar Screen

Analysis:- Number None Date By whom

OUTLET:- Where to Ditch to Mad River

Description:	Size and Shape	Material	Location	Elevation
1.	10 inch. Circular	V. C. Tile	South from	
2.			Plant	
3.				

Gaging possibilities Weir Possible in Narrow Ditch

Conditions below outlet: Color Red

Turbidity Deposits in Ditch and along Bank of River

SANITARY SEWAGE: Disposal Privies and 6" Sewer to River Persons tributary 100-125

REMARKS Housekeeping Methods Better than Average. Packing: 1937-75,000 Cases. 1938-50,000. 1939-50,000 (Expected) Well: 6" Casing, 120' Deep Gravel - Turbine Pump 20 g.p.m.

Survey by E. P. Brown Date 8-24-39

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an actual cannery)

River Mileage Index No. MiMa-130.8

Type of Plant Tomato Cannery State Ohio

Name of Plant West Liberty Canners

Municipality West Liberty Main Watershed Miami

County Loga Sub-Watershed Mad River

Address West Liberty

Source of Information J. L. Dee - Supt. & Owner

Plant Operation:- Average:- 60 hours per week - 30 days/year
100 employees plant - 3 office

Maximum:- 72 hrs.per week - 10-12 days/year
110-115 employees plant - 3 office

Seasonal Variation:- Operate from Aug. 10-15 to Oct. 1-10 or until killing frost.

(Survey report continued on next page)

Survey by E. P. Brown Date 8-24-39

Sewered Population Equivalent Computation:-

Factors used per case of No.2 cans (or per bushel) per day

B.O.D. 1.5 Suspended solids 0.6

Sewered population equivalent based on B.O.D. 3,000

Sewered population equivalent based on suspended solids 1,200

Remarks: Due to care in plant, estimates of sewered population equivalent may be higher (possibly 20 per cent) than actual.

Computation by: John Jones Date Sept.12,1939 Cincinnati Offi

Note: - This computation is of a preliminary nature and may b subject to revision as more information on this plant or the factors used becomes available.

West Liberty Canners MiMa-130.8

Water Supply - Municipal supply and private well. Municipal supply used only when well is inadequate.

	Gallon per day		
	City	Well	Total
Average	3,000	12,000	15,000
Maximum	8,000	12,000	20,000

Boiler water softened - no other treatment.
Well - 6 inch casing, 120 ft. deep, gravel, 20 g.p.m. turbine pump.

Products Canned - Chiefly whole tomatoes. Average 60,000 cases No. 2 cans per year (including 4000 - 5000 cases puree and juice)

1937 - 75,000 cases No. 2 cans.
1938 - 50,000 " " " "
1939 - 50,000 " " " " (expected)
Normal daily pack 2000 cases.

Wastes - Ave. 15,000 g.p.d. estimated from pump capacity and water bills.

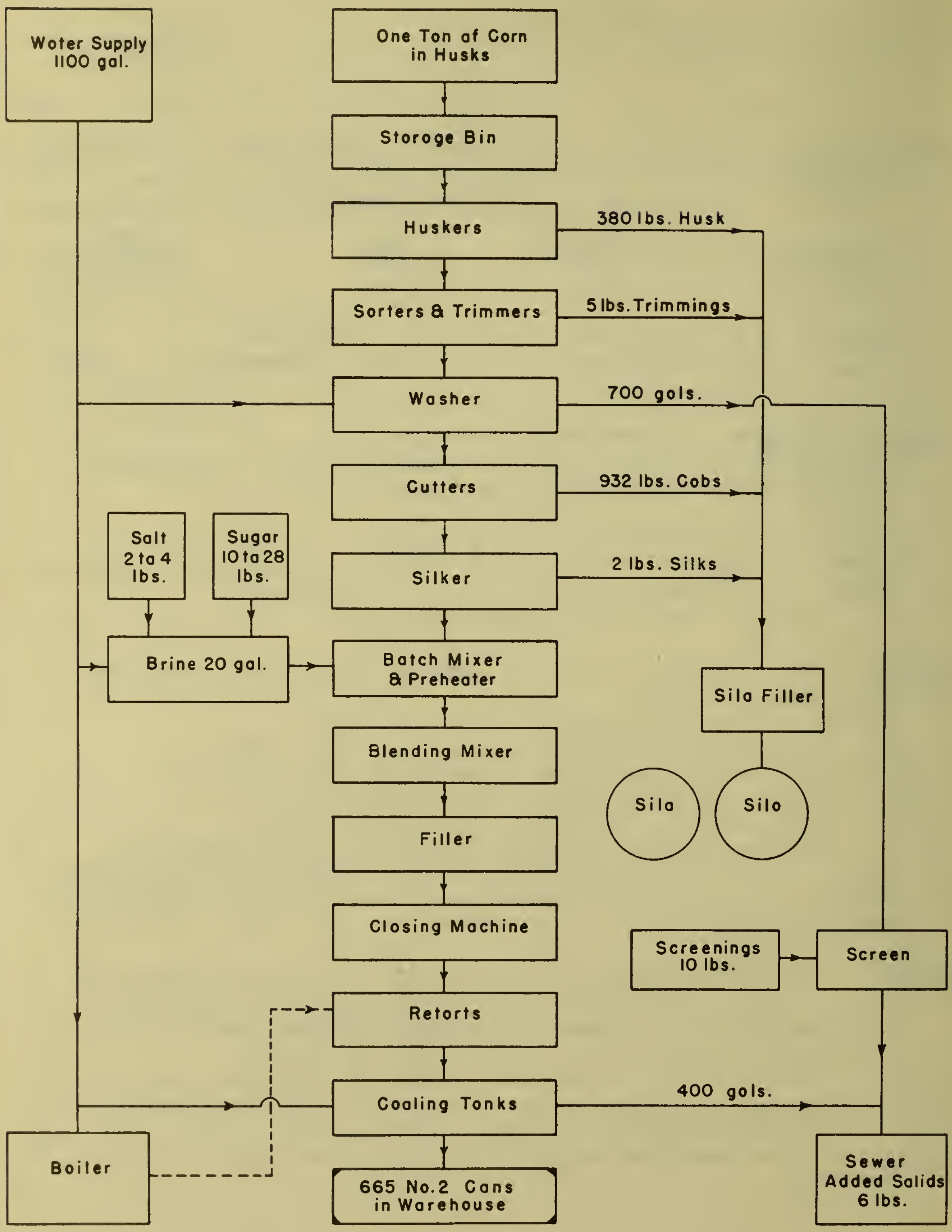
Skins, cores, etc. hauled to farm land.
Filler may overflow occasionally.
Bar screen on outlet. No analyses.
Appearance - reddish. Visible solids.
Segregation of strong wastes:- None except as noted. Practice of disposal of concentrated material, spills, etc. on farm land could be extended without difficulty.

Outlet - to narrow ditch to Mad River. 10 inch circular V. C. tile south from plant. For gaging weir could be installed in ditch. Red color below outlet. Deposits in ditch and along bank of river.

Sanitary Sewage - 6 inch sewer to river. Also privies.

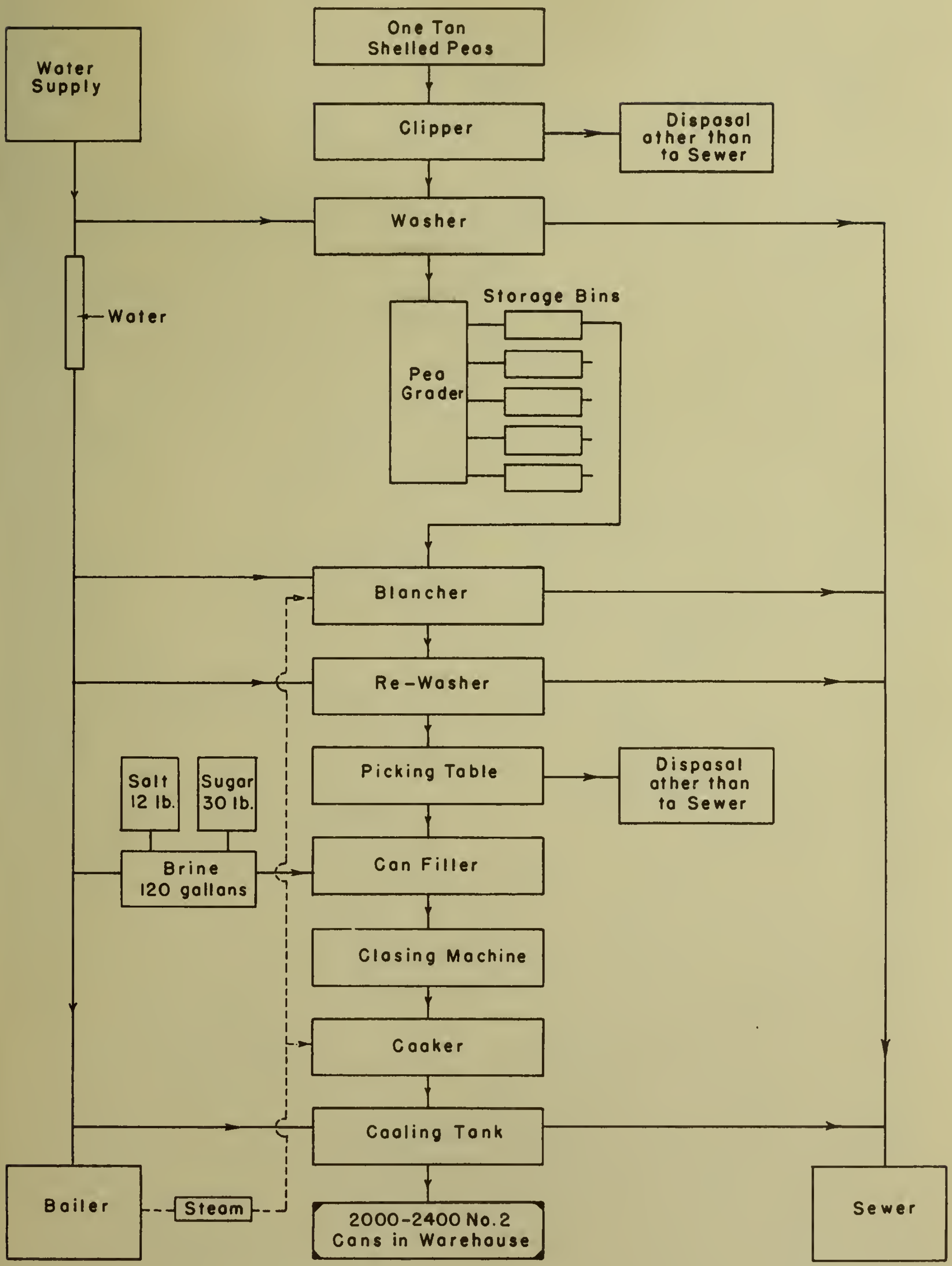
Remarks - Housekeeping methods appear to be better than average.

FLOW DIAGRAM
CORN CANNERY



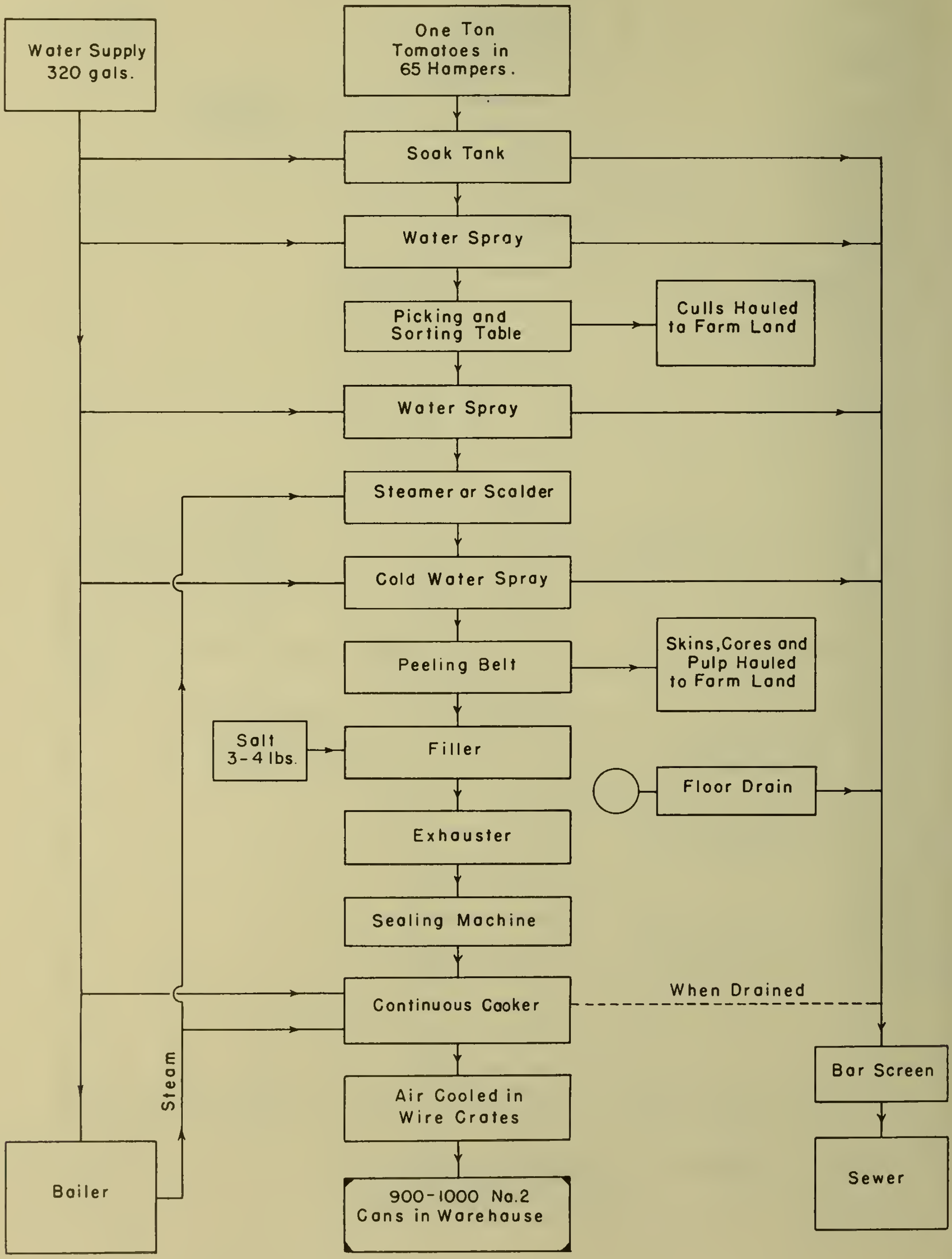
OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

FLOW DIAGRAM
PEA CANNERY



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942.

FLOW DIAGRAM
WHOLE TOMATO CANNERY



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

COAL WASHERIES

An Industrial Waste Guide to the Coal Washery Industry

APPENDIX "III" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract Cw-1
General Information Cw-2
Description of Coal "Washing" Processes Cw-4
Plant Operation Cw-9
Raw Materials and Products. Cw-10
Waste Discharges. Cw-12
Water Supply. Cw-14
Pollution Effects Cw-15
Treatment of Wastes Cw-16
Bibliography. Cw-18
Note Taking Form. Cw-19
Inspection Report Cw-20
Flow Diagram. Cw-22

List of Tables

Cw-1 Bituminous Coal Cleaned, 1935-36, by Classes of Equipment (Central Washery Plants Operated by Consumers in Colorado and Penn. included) Cw-7
Cw-2 Total Production of All Bituminous Coal at Mines with Cleaning Plants, 1935-36, in Net Tons. Cw-8
Cw-3 Cost of Cleaning Fine Anthracite. Cw-9
Cw-4 Typical Analyses of Raw and Cleaned Coal, and Discarded Refuse. Cw-10
Cw-5 Operation Records on a Coal Refuse Salvage Plant Cw-10
Cw-6 Relation in 1936, by States, between Total Bituminous Coal Production, Amount Cleaned, and Results from Cleaning Operations. . . . Cw-11
Cw-7 Anthracite Coal Production in Pennsylvania Cw-12
Cw-8 Analyses of Coal Washery Influents and Effluents Cw-13
Cw-9 Stream Analyses in the Vicinity of "Gob" Piles Cw-14

Abstract

The coal "washing" process consists of the separation and removal of noncombustible material to produce a superior product with a uniformly low ash content. This result has been most generally accomplished by the use of hand picking and pneumatic, magnetic and hydraulic machines.

Hand picking of coal with disposal of rejected material to fills and dumps starts at the coal-face. Pneumatic and magnetic separation is attained by use of air and magnetized belts or rolls. The impurities collected are again deposited chiefly in fills or dumps, although magnetic separation may yield material of value.

Hydraulic methods of separation depend on specific gravity differences. Water is generally used, although oils and solvents have served and these are sometimes used in conjunction with water. Water, acting as a carrier of the impurities, has been either discharged directly or passed through recovery equipment, and conditioned for reuse. Sludge from the wash water consists of fines and culm, which, after proper reduction of moisture content, may be discharged to dumps, mixed with other sizes to regulate ash content, or shipped separately for stoker consumption.

Nuisances and complaints resulting from the discharge of wash waste to the stream, are generally due to the presence of solids or sludge. Dumps and fills, not intelligently located, may contribute considerable quantities of solids by bank erosion or seepage through the refuse. The resulting deposits on the bottom and along the stream banks impair recreational facilities, damage sand and gravel qualities and reduce the general appearance of the stream to an unattractive black streak. The solids blanketing the stream beds no doubt have a destructive influence on fish food.

Present limited available information indicates that oxygen requirements of washery wastes are of minor consequence. Acids contributed to streams from sludge and gob piles,through underdrainage, have at times become serious.

Objectionable pollution from coal washeries can generally be eliminated by sedimentation and reuse of water in a closed system. These methods are practiced at a number of washeries, either to correct pollution or because of a necessity to conserve water.

Sludge and gob pile contribution to stream pollution can be materially reduced, if not completely eliminated, by proper selection of location and systematic drainage through open ditches or covered waterways.

General Information

The practice of washing coal developed many years ago in England, France and Germany, and many of the methods employed today in this country were developed in foreign coal fields. Coal washing usually is taken to mean more than separation of coal from dirt or impurities by use of water. Many practices today employ the use of dry methods to accomplish the same purpose, all of which are spoken of as "washing" coal. Although statements in this guide refer to bituminous coals, these statements, in most cases, are applicable to the anthracite industry as well.

Coal cleaning equipment and facilities are generally housed near the mine entrances. The general name applied is usually "preparation plant" and includes the sizing, and car and truck loading machinery, as well as the washery. This name, however, is not accepted in all coal mining fields. In Kentucky, the preparation plant is spoken of as the tipple and washery, while it is understood that this same combination in the anthracite fields of Pennsylvania is spoken of as the colliery or breaker.

The preparation plant consists of: (1) crushers for breaking the coal down to the desired sizes, (2) screens for separating these sizes to the required fractions, (3) the washery for separating the impurities from the coal, (4) recovery machinery for reclaiming coal from water, (5) inspection conveyors, (6) driers, (7) oilers, and (8) loading and handling machinery. Waste treatment facilities may also be mentioned here as part of an up-to-date plant but not all operations include this refinement.

Impurities in coal consist of shale, clay, pyrite or marcasite, calcite and gypsum, all of which, except the clays, are usually found in the beds. The clays may make up the roof or floor of the mine and, although they are separated from the raw coal as to position, it is difficult to extract the coal free from clay, especially if carelessly handled.

Impurities combined with the carbon and spoken of as "fixed" structural impurities consist of mineral matter, part of which is inherent sulphur, prevalent in the vegetable deposits forming the coal. These cannot be removed by washing and, therefore, washing is limited to some extent in "purifying" the coal.

Many of the industries of today employing the use of coal require it to be of specified sulphur content. The metallurgical and ceramic products industries are typical of those requiring such regulation. The American Society for Testing Materials has set up the following regulations pertaining to limitations of sulphur content of coal used in the manufacture of various products:

Product	Maximum Sulphur Content of Raw Coal
Blast furnace coke	1.3 percent
Foundry coke	1.0 "
*Ceramic products	1.3 "

* Discoloration is the governing factor and sulphur content depends upon the products manufactured.

High sulphur content is objectionable for use in power plants where, if burned with high moisture content, it increases the corrosive action of the flue gases.

Ash-forming impurities such as clays, shale, etc., reduce the ultimate value of the fuel. Two other impurities generally associated with coal are pyrite and marcasite, which are also ash-forming impurities. They are the source of iron and are further objectionable in forming clinkers.

The general advantages of washing and cleaning coal are: (1) increased sales and price, (2) increased heat value, (3) maximum useful application of heat evolved, and (4) elimination of freight and cumulative handling costs on refuse. High quality coal is demanded by the consumer, and the producer is required to meet this demand. Methods used are first governed by the condition of the raw coal. Some coals require only crushing and screening into sizes; others require screening, mechanical cleaning and hand picking. The best preparation requires all steps previously mentioned, plus additional refinement by dry or wet processing. As a rule, the maximum refinements demand the maximum price, although this is not altogether true. Steel companies and private consuming industries who mine their own coal institute refinements to secure a fuel to fit their own particular needs. Nearly all anthracite fuel is cleaned and washed.

Many improvements have been made and developed since the cleaning of coal began. As a result, waste of this fuel is reduced and the finished product is of higher quality. Refinements and improvements in methods have made it economical to rework old refuse piles in the anthracite fields.

Description of Coal "Washing" Processes

As has been previously stated, coal "washing" is a term generally applied to the cleaning of coal. The methods used are many, several of which may be practiced at the same plant. The first two always used are mine and breaker picking and screening. Screening and breaker picking often are preceded by crushing to reduce to the desired fractions, and screening may be resorted to between other operations which might follow.

Mine and Breaker Picking

Mine and breaker picking are carried out by the miners and employees in the cleaning plant. As the coal is blasted or dug from the beds preparatory to being loaded in cars, many impurities, such as shale, present themselves in large masses. These are singled out by the miner and detoured to the refuse dumps. As the coal moves through the preparation plant on metal or rubber conveyors, employees are stationed nearby to pick out the impurities, with discharge to refuse piles. These practices reduce considerably the impurities in the coal in many cases, and lessen the load on other processing which follows.

Screening

Screening is followed by all preparation plants and consists of separating the coal into various sizes from 6-inch to very fine, according to the desires of the operator or suitable to the demands of the consumer. Some coals with high ash content are only retained down to a certain small size. Fractions below this size are discarded to dumps. Screening is often necessary preceding many of the processes which follow in the preparation plant.

Air Cleaning

Air is used in the preparation plant for cleaning. Dedusting is sometimes practiced on coals before going through the washery. This amounts to nothing more than a stream of air directed through a screen to carry away the lighter clays, etc., which are usually caught in a cyclone hood and discharged to the dump.

Wet Processes

Wet processes of washing and cleaning coal are accomplished by the use of: (1) trough washers, (2) launders, (3) piston and pan jigs, (4) rising current classifiers, and (5) table concentrators. These machines all use the gravity stratification principle and are similar to the air classifiers, except that the medium employed is water. In all cases the coal and water must be kept in a mobile state by either continuous discharge of water or swelling of the moving mass as in the piston jigs.

The disadvantages of this method are: first, the wash water must be disposed of to the stream or "purified" for recirculation and, second, the product picks up considerable moisture and requires drying.

On emerging from the washers, screening classifies the larger coal over about the 3/16-inch size. The larger fractions are routed to storage or cars unless tests prove that further breaking down of the coal to free more impurities will prove economical. In this case the products receive further crushing and are returned to the washer. The fines or fractions below the 3/16-inch size are discharged with the water either to the stream, to ponds or to settling tanks. More generally settling tanks are used, whereby these fines can be reclaimed and sold for stoker fuel or mixed with the larger sizes for building up ash content. In preparation of stoker fuel it is necessary to reduce the moisture content and this is accomplished by means of centrifugal driers.

Settling tanks for recovery of fines are equipped with drag conveyors which are continuously operated. The effluent is either discharged to the stream, returned to the washer or passed on for further purification before entering the washer or being discharged to the stream. In closed systems, water is never discharged, and make-up water to take the place of natural evaporation or moisture carried out in the coal or refuse material is generally supplied through the final spray of a series used on the finished product.

Refuse material from the washers is usually disposed of on dumps and fills. In the case of table-type washers, valuable pyrite may be salvaged as a by-product.

Other wet processes involving the specific gravity principle include sand, clay, zinc chloride, calcium chloride and magnetic flotation. Any of the first five of these are combined with water to produce a medium of increased specific gravity, whereby impurities can be separated for the desired result. In magnetic flotation, magnetized conveyors, plus the buoyancy of water, separate the impurities. In all cases the difficulty of separating the coal from the water and cleaning the effluents is a disadvantage.

Wet processes of the nongravity type include froth flotation and the recently introduced oil "amalgam" type (Trent Process).

Magnetic Processes

Many plants use magnetic belts or rolls, in addition to other cleaning equipment, to separate "tramp" iron from the coal. These facilities generally precede other operations and considerably reduce the load to the main plant.

Other processes which might be mentioned include sand flotation and electrostatic separation. These do not involve the use of water although the first comes under the float-and-sink group and depends upon the specific gravity of the raw product to separate out in a bed of sand. Electrostatic separation is of the nongravity type, and while it can be used on coal it is best suited for cleaning ores.

Oiling

Although oiling of coal may not be considered a cleaning step, yet to some degree it accomplishes that purpose. It settles the dust in the coal and prevents excessive cleavage and breakage. It is applied to the coal through high pressure sprays, in quantities to meet the demands of the consumer. Reported quantities used are 5 to 6 quarts per ton of coal.

Table Cw-1, Bituminous Coal Cleaned, 1935-36, by Classes of Equipment (Central Washery Plants Operated by Consumers in Colorado and Pennsylvania Included)

Types of Equipment	Plants in Operation		Net Clean Coal (Million Tons)		Percent Cleaned by Each Type	
	1935	1936	1935	1936	1935	1936
Wet Methods:						
Jigs	138	154	15.7	23.4	34.7	38.3
Concentrating Table*	9	8	1.1	1.8	2.5	3.0
Jigs Combined with Concentrating Tables*	15	16	1.5	2.6	3.4	4.3
Launders and Upward Current Classifiers	93	98	18.4	22.6	40.7	37.1
Total- Wet Methods	255	276	36.9	50.5	81.3	82.7
Pneumatic Methods	65	66	8.5	10.6	18.7	17.3
Grand Total	320**	342**	45.4	61.1	100.0	100.0

* A more representative figure for the use of wet tables is indicated by combining the totals for concentrating tables with the total for jigs used with concentrating tables. This shows a net gain of 1.8 million tons (67.1 percent) for 1936.

** Plants using both wet and pneumatic types: 32 in 1935;
31 in 1936.

Table CW-2, Total Production of All Bituminous Coal at Mines with Cleaning Plants, 1935-36, in Net Tons

(Does not include any estimate for mines that may ship to consumer-operated plants)

	Millions of Tons	
	1935	1936
Wet Methods		
Jigs	34.9	49.0
Concentrating Tables	1.5	1.2
Jigs in combination with concentrating Tables	1.8	2.8
Launders and upward-current Classification	37.8	47.9
Total Wet	76.0	100.9
Pneumatic Methods	24.0	30.0
Grand Total	100.0	130.9
Less Duplication*	12.8	15.5
Net Total	87.2	115.4
United States Production of Bituminous Coal	372.4	439.1
Percent Produced at Mines with Cleaning Plants	23.4	26.3

* Mines using both wet and pneumatic methods.

Plant Operation

The average operating time of a preparation plant is 7 to 9 hours daily although some plants require 20 hours maximum. This depends upon the capacity of plant, sizing of product, refinements followed, condition of raw coal and efficiency of equipment. Records are available on washing plants with capacities ranging from 150 to 8,500 tons per day. Many plants prepare for market a good portion of the coal produced by crushing and screening, with the balance going through the "washery." It is therefore difficult to set up any comparative cost schedule in lieu of variations which seem to exist. Records are available to show that installation costs vary between $500,000 and $1,800,000 per 1,000 ton-hour capacity, including complete treatment of slurry, and that this treatment installation cost averages around 2 to 5 percent of total investment.

Employees required to operate a preparation plant depend upon the activities in the plant itself. As most mechanical operations are controlled from one panel, one employee in the "washery" is sufficient to handle a good sized plant. Picking and loading operations influence the number required for the plant as a whole. Available information indicates that 12 to 20 employees are required to operate plants from 500 to 1,000 ton-hour capacity.

Cost of cleaning fine anthracite with jigs and tables is shown in Table Cw-3 in cents per ton (by Hobart):

Table Cw-3, Cost of Cleaning Fine Anthracite

Item	Cost in Cents per Ton	
	Jigs	Tables
Maintenance and operation	3.60	1.27
Power	.47	.15
Depreciation	.20	1.20
Water supply	.26	.13
Total (cents per ton)	4.53	2.75

Raw Materials and Products

Run of the mine coal contains many impurities, some of which can be easily separated while others give considerable trouble and increase the facilities necessary for handling. The "ROM" (Run of the Mine) may vary considerably from one day to the next so that it is impossible to set up any relation between raw material and product.

The ash content in the finished product is generally maintained by mixing fines (high in ash) with the sized coal. A typical analysis of coal in various classes is shown on Table Cw-4.

Table Cw-4, Typical Analyses of Raw and Cleaned Coal, and Discarded Refuse.

	Raw Coal 100 percent	Cleaned Coal 94.59 percent	Refuse 5.41 percent
Volatile matter	18.60	18.65	12.09
Fixed carbon	72.45	74.75	34.91
Ash	8.95	6.60	53.00
	100.00	100.00	100.00
Sulphur	.84	.83	1.20

Some localities have coal mines sufficiently high in pyrites to warrant operation of washeries to recover this material. This operation is generally accomplished by the use of concentration tables.

A record of operation of a refuse plant is here given:

Table Cw-5, Operation Records on a Coal Refuse Salvage Plant

Year	Days	Men	Coal Salvaged in tons	Pyrite Produced in tons
1937	266	15	42,052	15,000
1938	320	24	39,950	17,757
1939	183	26	4,494	11,018

Refuse produced at preparation plants is discharged to dumps and fills, generally along the bed of a stream. Refuse produced amounts to between 4 and 5 percent of cleaned coal production for the country as a whole. Some plants, giving little or no treatment to washery wastes, discharge them through drilled holes to old mine workings.

Table 6 - Relation in 1936, by States, between Total Bituminous Coal Production, Amount Cleaned, and Results from Cleaning Operations.

Bituminous Production by States	Total Production of Mines With Cleaning Plants (Millions of Tons)	Result of Cleaning Operations (Millions of Tons)			Percent of Refuse to Raw Coal	Percent of Clean Coal to Total Mine Production
		Coal Cleaned	Clean Coal	Refuse		
Alabama	11.14	11.12	9.92	1.20	10.8	89.1
Colorado	*	*	*	*	8.5	26.6
Illinois	17.19	6.67	5.61	1.06	15.9	32.7
Indiana	4.85	2.56	2.20	0.36	14.0	45.3
Kentucky	2.50	0.56	0.51	0.05	8.9	20.6
Missouri and Kansas	2.35	2.05	1.77	0.28	13.7	75.4
Ohio & Michigan	2.88	1.54	1.33	0.21	13.3	46.2
Pennsylvania	*	*	*	*	6.9	53.0
Tennessee	0.55	0.31	0.26	0.05	15.7	46.8
Virginia	1.85	0.55	0.47	0.08	14.0	25.6
Washington	1.50	1.43	1.20	0.23	15.8	80.1
West Virginia	42.03	16.41	15.36	1.05	6.4	36.5
Undistributed**	28.56	15.83	14.74	1.09	5.5	22.0
Total at Mines Only	115.40	59.03	53.37	5.66	9.6	46.3
Consumers Plants		8.13	7.71	0.42	5.2	
Grand Total		67.16	61.08	6.08	9.0	

* Included in "Undistributed."

** Includes Arkansas, Colorado, Maryland, Montana, New Mexico, and Pennsylvania. Percentage figures represent results for Arkansas, Maryland, Montana, and New Mexico only.

The raw materials at some of the coal preparation plants include refuse banks and culm piles. This is particularly true in the anthracite region where these piles are being worked over. In 1938 the amount of anthracite coal reclaimed amounted to

2,340,444 net tons, a portion of which was passed through the breakers.

Another source of production of anthracite coal is through dredges working along the streams to reclaim fines discharged by mining operation nearer the headwaters. The extent of various operations in Pennsylvania is shown in Table Cw-7 together with the total production.

Table Cw-7, Anthracite Coal Production in Pennsylvania

	Millions of Tons				
	1934	1935	1936	1937	1938
State (excluding Sullivan County):					
Breakers*	55.14	49.27	51.46	48.98	43.60
Washeries	1.19	2.11	2.35	2.02	1.88
Dredges	0.65	0.59	0.55	0.76	0.57
Sullivan County:					
Breakers	0.19	0.19	0.22	0.09	0.05
Totals	57.17	52.16	54.58	51.85	46.10

* Breaker product includes a certain amount of culm bank coal; 617,000 tons in 1935; 987,000 tons in 1936; and 561,960 tons in 1938.

Waste Discharges

Many sources of waste discharge are prevalent at a preparation plant, although some occur primarily in a dry or semi-dry state. Plants operating with wet processes probably contribute more than all the others put together, especially if no treatment is practiced. Operations with closed systems require cleaning occasionally, or closing down for repairs, in which case tanks or basins may be discharged to surface drainage. Failure of dikes or terraces may also contribute considerably to the discharges, while spills and drainage of equipment and transporting vehicles should not be overlooked.

Table Cw-8, Analyses of Coal Washery Influents and Effluents*

Source Results in p.p.m.	Acid $CaCO_3$ Phen.	Alk. $CaCO_3$ M.O.	Hardness $CaCO_3$	Total Iron as Fe	Solids		B.O.D. 5-day 20°C.
					Total	Suspended	
Plant "A"							
Raw Water	12	-	128	2	-	-	3.7
Discharge	-	86	1,002	850	-	-	-
Plant "B"							
Raw Water	8	280	155	-	728	-	1.9
Discharge	8	228	150	-	108,000	101,000	-
Plant "C"							
Raw Water	20	92	385	-	1,290	-	1.6
Discharge	8	108	380	-	49,900	41,600	20
Plant "D"							
Discharge	8	144	90	-	208,000	201,000	10

* Records of coal washery effluents are few. Table 8 shows the results of analyses on grab samples which indicate the conditions at four plants.

Dry materials, from dusting and screening operations, go in with the general refuse discharge to fills and dumps. These deposits are rarely of sufficient distance from the streams to prevent stream wash, and although the material packs readily, erosion from rains and freshets may be the source of large quantities of slurry.

Some plants, after partial treatment of wastes, discharge them to old mine workings through drill holes or back of refuse piles, both of which may be of unsound judgment in that the drainage of wet material will produce acid loadings on the receiving stream. Table Cw-9 shows by analyses the effect of waste piles on streams.

As the quantity of impurities present may vary in coal from different locations and preparation plants are so widely different in their operations, it is impossible to draw up any comparative scale based on discharge of solids.

Table Cw-9, Stream Analyses in the Vicinity of "Gob" Piles

Determination	Gob Pile "A"		Gob Pile "B"		Gob Pile "C"	
	Above	Below	Above	Below	Above	Below
Run-off in M.G.D.	0.072	0.086	0.720	0.864	0.058	0.058
pH	3.3	3.1	2.8	3.0	5.3	3.2
Total Acidity by Phen. p.p.m.	80	240	880	1350	8	120
Acidity Cold M.R. p.p.m.	50	180	420	680	4	90
Total Acid in Lbs. per day	48	173	5280	9720	4	96

Table Cw-10, Estimated Quantities of Refuse from Selected Small Wet Coal Cleaning Plants

Raw Coal Tons Daily	Refuse Tons Daily	Type System
250	2	Closed
200	10	*
1150	90	*

* Partial overflow to stream.

Water Supply

Water supply for use at washing plants is generally obtained from wells, streams or mines. Wells rarely supply the entire consumption as the cost of drilling would prohibit such expenditure when other means are available. Streams are the common source, although treatment may be necessary, especially if the water is highly acid. Mine water is often used and in slope mining regions may furnish complete requirements under gravity head. Mine water, however, if acid, usually requires treatment.

Water is used in a preparation plant mainly for supplying a medium whereby impurities can be separated from the coal and to act as a vehicle for the removal of these impurities.

Quantities of water consumed vary considerably in the various plants, and largely depend upon the type of operations carried out. In closed systems the make-up water depends mostly upon the quantity of moisture carried out with the coals and refuse, and therefore has a direct bearing on the quality of the coal and the amount of equipment employed. The quantity of water circulated per ton of washed product is fairly constant for a wide range of capacity using the same type of equipment, but varies considerably with different methods. The amount of impurities removed will also affect the quantity of recirculated water. It is stated that the skillful use of the principle of withdrawing a portion of the dirty water from appropriate places in the flow system to be clarified or discharged to sludge ponds can largely overcome differences in water circulation quantities.

It is therefore apparent that the quantity of water, make-up and recirculated, depends upon the efficiency and types of methods employed in washing, analysis of raw product and clarification of washing wastes.

Water consumed, if taken from stream or mine, may be highly acid and require treatment in separate equipment before entering the preparation plant or may be neutralized by adding an agent such as hydrated lime to the settling basins. Some coals increase the acidity of water consumed and may make it necessary to treat the water after contact with the product.

Pollution Effects

From available information which is somewhat limited, it is doubtful if waste slimes discharged from coal washing activities has any serious bacteriological effect on the streams. The biochemical oxygen demand of effluents is very low and compares favorably to a healthy stream.

General opinion is that coal washery wastes are acid. This appears not to be true, however, and several reasons may be noted in explanation. Many mines "rock dust" the workings with pulverized limestone to reduce explosion hazards and a sufficient amount of this dust is transported with the coal to the washeries to neutralize the acids formed. It is also believed that without "rock dusting" an ample supply of natural limestone is mixed with the coal in mining to produce alkaline waste effluents.

Solids discharged to surface waters direct from washeries and indirectly from sludge and refuse dumps may cause considerable nuisance to recreation beaches, impair the quality of sand and gravel deposits, and reduce the tangible value of inundated lands. Numerous references indicate that black carbon fines may be carried many miles downstream to be deposited along the bank or spread over the bottom. On certain streams in the anthracite fields of Pennsylvania, the river beds are sufficiently covered to make recovery of coal fines profitable. Sand and gravel companies are reported seriously objecting to carbon particles in their product, which are a result of waste discharges; also nuisance complaints by boating interests in lower Schuylkill Basin are recorded. From tests available on fertility of soils, no objection can be raised due to inundated farm lands with this waste. However, because of the compactibility of these solids, soils may become difficult to work and their appearance may be repulsive. Another objection to the depositing of these solids in streams is possible damage to fish food.

Treatment of Wastes

Many types of machines and equipment are used to clarify coal washery wastes. These may employ settling, filtering and coagulation. Practically all plants practice recovery of fines, especially if wet processing is used. This consists of settling the water in tanks, and using flight conveyors to draw out the settlings. The slurry, or overflow from the tanks, may be: (1) discharged to the stream, (2) continued through further settling and treatment with eventual recirculation, or (3) recirculated with dilution water added for make-up.

Additional treatment following recovery of fines may consist of further settling in ponds, Imhoff cones, or rotary thickeners, with drying of sludge in centrifugal forced heat equipment. Effluents from ponds may be discharged to surface drainage or pumped for recirculation.

The use of coagulants such as swollen potato starch and lime are reported to improve the performance of filters and thickeners.

Wastes with quiescent settlement from 30 minutes to one hour are reported to show a supernatant liquid which is free of visible matter but is slightly darkened due to suspended matter. Final settling basins require cleaning from time to time to retain effective depth and detention time. This sludge is generally deposited behind dumps or along the terraces of the ponds.

Present information indicates that the best treatment of coal washery wastes involves chemical precipitation or settling aided by the use of coagulants. In plants with closed systems the treatment is sufficient and the nuisances and complaints have been eliminated.

Wastes from gob or refuse piles may be eliminated or considerably reduced by several remedial measures. Selection of the proper location should be the first consideration in depositing this waste, where drainage can be minimized and controlled. Old dumps can be isolated from stream courses by rerouting through new channels or by tunneling the piles and installing conduits. Seepage and drainage from dumps can be restricted, by ditching and retention in ponds, well terraced.

Bibliography

1. Chemical Abstracts Vol. 30, 1936
   Purifying Coal Washing Slurry Liquor

2. Chemical Abstracts Vol. 32, p. 5730
   The Clarification of Coal Washery Slimes

3. Coal Age Vol. 44, 1939, pp. 44-48
   Efficiency in Cleaning

4. Engineering Vol. 147, 1939, pp. 639-641
   Coal Cleaning Plant at Wingate Colliery, England

5. Coal Age 1940
   Coal Reclaimed from Slate

6. Bureau of Mines Bul. 300
   Coal Washing Investigation (Methods & Tests)

7. U. S. Congress - Hearings Senate Commission 1936
   Stream Pollution

8. Coal Age Vol. 22, 1922, pp. 751-757

9. Coal Age Vol. 22, 1922, pp. 664, 847

10. Coal Age Vol. 19, 1921, pp. 810, 993

11. Coal Age Vol. 21, 1922

12. Coal Age Vol. 24, 1923

13. A Digest of Industrial Waste Treatment, April, 1940
    by Christian L. Siebert, Executive Engineer,
    Pennsylvania Dept. of Health

14. Private Communication

15. U.S.P.H.S. Stream Pollution Files

16. 1939 Report Mine Inspection Division, State of Kansas

17. Minerals Year Book, 1939

COAL WASHERY WASTES (Not an Actual Plant)

Plant Black Diamond Coals, Inc. State Kentucky Ref.No. S 85.5

City Black Diamond County Coal Main Watershed Salt River

Address R D # 2 Sub-watershed

Informant U. A. Jones Title Tipple Foreman

Plant Operation:

	Hours per Week	Days per Year	Plant Employees
Average	35	130	12
Maximum	55	50	12

Seasonal variations Depends upon mining operation and sales

WATER SUPPLY:-

	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	Well	Negligible		None
Industrial	Mine	35,000	50,000	None
Cooling	None			

Make-up water only

RAW COAL ENTERING PLANT DAILY:- 250 T. (Full capacity)

Fractions: Crushed 6" x 0" Washed 1" x 0"

Recovered 1/4" x 0 Recrushed 4" x 1½"

Chemicals

SULPHUR CONTENT:- Raw Coal 1.2 % Refuse 2.1 %

COAL LOADED OR STORED DAILY:- 235 T. (approx.)

WASHING AND PREPARATION PROCESSES:- Rheolaveur trough washers, hand picking magnetic separation belt

WASTES:- Quantity Closed system How estimated Make-up by pump rating

Recovery Eff. to treatment Dryer Eff. to treatment

Clean-outs:- once monthly (pumped to pond with seepage to ground)

Disposal other than water carried:- pickings & refuse 12.5 T. daily piled 200' ± from stream

Spills or Other Wastes

Treatment Settling tank 60' x 15' x 8' – Settling cones (primary & secondary)

Analyses:- Number 26 Date Nov. 1940 By whom Company

Appearance pH 7.5 (tests daily)

OUTLET:- Where to None

Description:

	Size and Shape	Material	Location	Elevation
1.				
2.				

Gaging possibilities None

Conditions below outlet: Color Stream appearance good

Turbidity Deposits

SANITARY SEWAGE:- Disposal Septic tank Persons tributary 12

REMARKS Mine water slightly acid at times and lime used

Survey by J. D. Reed Date 11 – 15 – 40

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES

River Mileage Index No. S 85.5

Type of Plant Coal Washery State Kentucky

Name of Plant Black Diamond Coals, Inc.

Municipality Black Diamond Main Watershed Salt River

County Coal Subwatershed ----------

Address R.D. #2

Source of Information U. A. Jones, Tipple Foreman

Plant Operation:-

Average - 35 hrs. per week, 130 days per yr.-12 plant employees
Maximum - 55 hrs. " " 50 " " " -12 " "

Seasonal Variation:-

Depends upon mining operation and sales.

(Survey report continued on next page)

Survey by J. D. Reed Date Nov. 15,1940.

Sewered Population Equivalent Computation:-

Factors used

B.O.D. Suspended solids

Sewered population equivalent* based on B.O.D.

Sewered population equivalent* based on suspended solids

Remarks: This plant has a closed water system, no wastes reaching the stream.

Computation by: M. L. Wood Date 11/25/40. Cincinnati Office

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
*Rounded to nearest 100

Black Diamond Coals, Inc.
R. D. #2,
Black Diamond, Ky.

Water Supply: - Private well for drinking. Mine supply for plant make-up. Average 35,000 G.P.D., Maximum 50,000 G.P.D. Mine water slightly acid at times and lime used.

Raw Coal Entering Plant Daily - 250 Tons at full capacity. Coal crushed to 6 inches, 6" x 1" to cars, 1" to 0 washed, ¼" x 0 finer sewered.

Sulphur Content - Raw coal 1.2%, Refuse 2.1%.

Coal Loaded Daily - 235 Tons (Approx.)

Washing and Preparation Processes - Rhevlareur trough washers, hand picking and magnetic separation belt.

Wastes - are treated and water is reused.

Clean-outs monthly are pumped to a pond. Pickings and refuse, 12.5 tons daily go to a gob pile about 200 feet from stream.

Treatment of wastes consists of a settling tank 60' x 15' x 8', and primary and secondary settling cones.

pH tests made daily average 7.5.

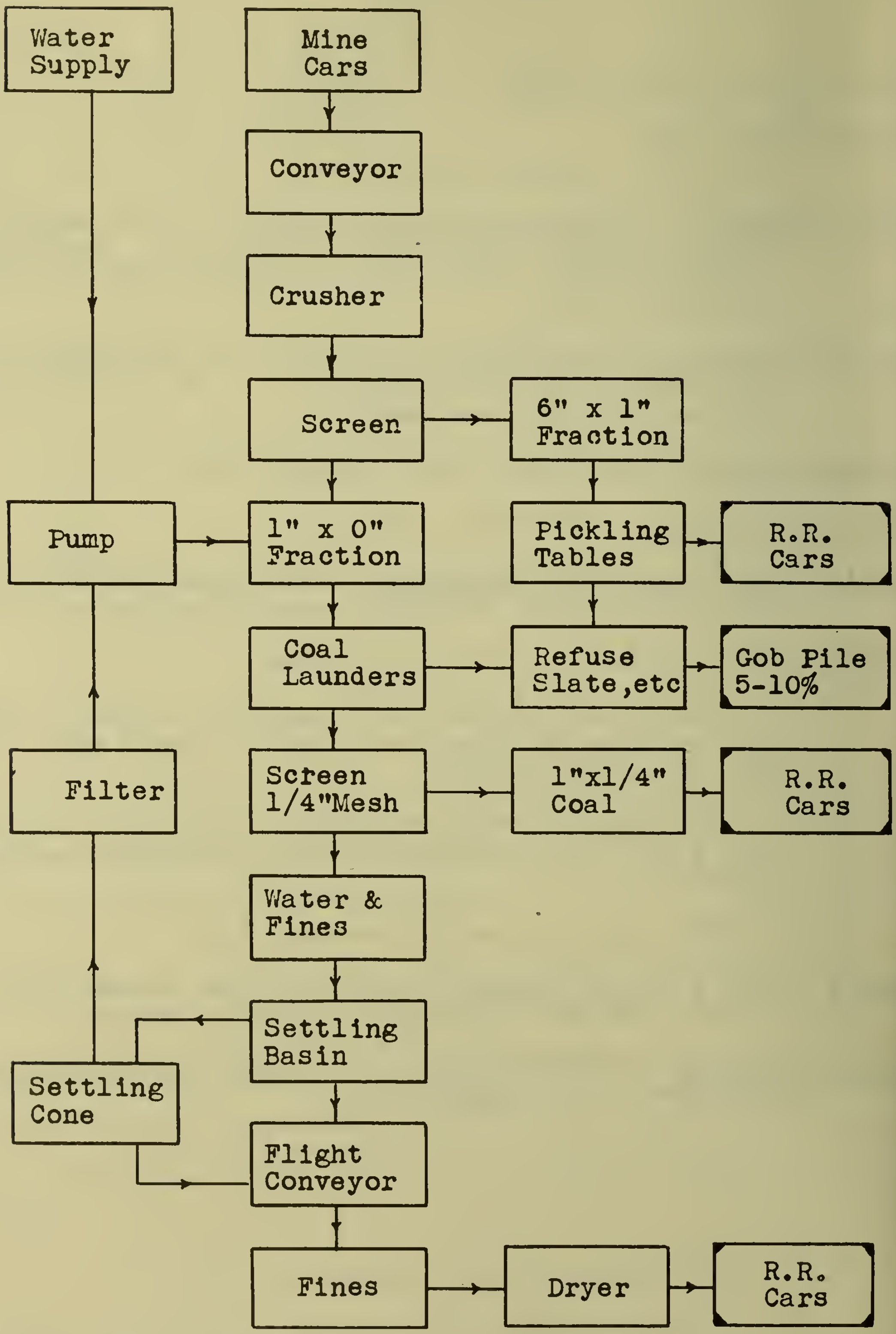
Outlet - There is no apparent outlet and the stream gives no evidence of the discharge of washery wastes.

Sanitary Sewage - is discharged to a septic tank and thence to Salt River. No complaints.

FLOW DIAGRAM

COAL WASHERY

Closed Water Recovery System



Ohio River Pollution Sur
U. S. Public Health Serv
1942

OHIO RIVER POLLUTION SURVEY

COKE

An Industrial Waste Guide to
the Coke Industry

APPENDIX "IV" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract. Ck-1
Description of Process. Ck-2
Raw Materials and Products. Ck-5
Sources and Quantity of Waste Ck-9
Character of Wastes Ck-13
Pollution Effects Ck-17
Remedial Measures Ck-19
Phenol Removal and Recovery Ck-22
Bibliography. Ck-28
Note Taking Form. Ck-31
Inspection Report Ck-32
Flow Diagrams Ck-36

List of Tables

Ck-1 Sources and Rounded Figures for Quantities and Strengths of By-Product Coke Plant Wastes. Ck-1
Ck-2 Raw Materials Used in By-Product Coke Plants Ck-6
Ck-3 Products and By-Products from By-Product Coke Plants . . Ck-6
Ck-4 Average Yield of Coke and By-Products in By-Product Ovens in the United States, 1920-1938. Data from Bureau of Mines Ck-7
Ck-5 Ratio of Employees to Raw Materials in By-Product Coke Plants Ck-9
Ck-6 Quantities of Wastes from Various Sources in By-Product Coke Plants. Ck-9
Ck-7 Volume of Ammonia Still Waste from By-Product Coke Plants Ck-10
Ck-8 Relation of Quantities of Ammonia Liquor to Ammonia Still Waste in By-Product Coke Plants. Ck-10
Ck-9 Volume of Final Cooler Water from By-Product Coke Plants Ck-11
Ck-10 Volume of Benzol Carrying Water from By-Product Coke Plants Ck-12
Ck-11 Volume of Cooling Water from By-Product Coke Plants. . . . Ck-12
Ck-12 Analyses of Ammonia Still Wastes from By-Product Coke Plants Ck-13
Ck-13 Analyses of Final Cooler Water from One By-Product Coke Plant (Plant F). Ck-14
Ck-14 Analysis of Final Cooler Water from Closed Recirculating System of a By-Product Coke Plant Average at Two 24-hour Composite Samples. Ck-14
Ck-15 Analyses of Benzol Purification Wastes from By-Product Coke Plants. Ck-15
Ck-16 Analyses of Combined Waste from By-Product Coke Plants Based on Limited Data. Ck-16
Ck-17 Sewered Population Equivalent of Combined Wastes from By-Product Coke Plants Based in B.O.D. Ck-16
Ck-18 Estimated Sewered Population Equivalents of Waste from Various Sources in By-Product Coke Plants. Ck-17
Ck-19 Survival Time of Goldfish in Phenol Contaminated Water . Ck-18
Ck-20 Survival Time of Resistant Fish (Hyborhynchus Notatus) in Phenol-Ammonia Contaminated Water Ck-19
Ck-21 Phenol Reduction in Ammonia Liquor by Distillate Coke Quenching in a By-Product Coke Plant Ck-24
Ck-22 Phenol Removal Efficiency of Vapor Recirculation Process in By-Product Coke Plants. Ck-25
Ck-23 Approximate Installation Cost, Vapor Recirculation Process for Phenol Recovery in By-Product Coke Plants. . Ck-26
Ck-24 Phenol Removal Efficiency of Benzol Extraction Process in By-Product Coke Plants. Ck-27

Abstract

The by-product coke process consists of the destructive distillation of coal to produce gas, coke, ammonia liquor and coal tar. From these, particularly the coal tar, a great many further products are derived although only the four primary products are customarily produced at the by-product coke plant.

By-product coke plant wastes are notable chiefly because of their phenol content which causes tastes and odors in public water supplies. However, oxygen requirements of the wastes, although less often mentioned, are of consequence.

Table Ck-1 gives quantities and rounded figures for strength and sewered population equivalents of the wastes broken down as much as is possible with present information.

Table Ck-1. Sources and Rounded Figures for Quantities and Strengths of By-Product Coke Plant Wastes.

Source of Waste	B.O.D. 5-da.20°C. p.p.m.	Phenol p.p.m.	Quantity of Waste Gallon	Sewered Population Equivalent B.O.D.(a)
			Per Ton of Coal Carbonized	
Ammonia Still	4000	2000	22	5
Final Cooler	650	100	315	4
Benzol Carrying	220	10	15	1
Cooling Water	-	-	3200	-
Other	-	-	-	5
Total	85	20 (b)	3600	15

(a) Based on 0.168 lbs. B.O.D. (5-da.20°C.) per capita.
(b) Computed.

Pollution reduction measures at by-product coke plants as now practiced are largely in the nature of changes within the plant. The nearest approach to actual treatment is in the reduction of phenol discharges and even here most methods used are of an industrial recovery rather than a treatment type.

Disposal of materials other than to the sewer include evaporation of a portion of the quench water, dumping of agitator acid wastes on slag piles and burning of the pure still residue.

Oxygen requirements of by-product coke plant wastes have received little attention. These requirements can be reduced by recirculation of final cooler water. A gravity oil separator on the light oil and crude still waste lines is desirable and refining or pure still residue should not be discharged to the sewer.

The removal of phenols from coke wastes has received considerable attention following public water supply taste and odor troubles. Efficient phenol recovery units are now in successful operation.

Description of Process

The process described in this guide is believed to be typical of a by-product coke plant using the direct system of ammonia recovery. There are two general methods of ammonia recovery known as the direct system and the indirect system, respectively. To avoid confusion and also because the direct system is the more common, it alone will be described.

Coal of a suitable quality, when heated in the absence of air (oxygen), can be destructively distilled to produce gas, coke, ammonia liquor and tar.

This destructive distillation is carried out in narrow horizontal retorts placed side by side. They are usually set in groups of from six to nine in what is known as a "bench". The group of "benches", varying with the capacity of the plant, is known as the "stack". The retorts are charged through openings in the roof, and discharged by a ram from one end.

The items of equipment following the stack and the purposes for which they are used in connection with the four products are briefly described as follows:-

Gas

(1) Ascension Pipe - a device connecting the by-product coke oven retorts with the collecting main. Gas receives some preliminary cooling from a spray of ammonia liquor at this point.

(2) Collecting Main or Hydraulic Main - large diameter pipes used to conduct gas, ammonia liquor, and tar from the retorts to the by-product recovery apparatus. Recirculating ammonia liquor further cools the gas during its flow through these mains.

(3) Primary Coolers - the retort gas is again further cooled by a powerful spray of ammonia liquor, the liquor, in turn, being cooled by the plant cooling water in indirect cooling coils.

(4) Decanter - a device to separate gas, ammonia liquor, and tar by taking advantage of their difference in density. A part of the ammonia liquor thus separated is returned, after cooling, to the primary coolers to reduce the temperature of the hot retort gas. The balance or excess ammonia liquor is piped to the ammonia liquor storage tank for ultimate recovery of ammonia.

(5) Exhauster - to create suction on the ovens and mains and to boost the gas above atmospheric pressure.

(6) Tar Extractor - after the major portion of the tar has been separated from the ammonia liquor in the decanter, the small amount of tar remaining in the gas is precipitated out by an electrical or mechanical process.

(7) Saturators - the partially cooled gas, now freed of ammonia liquor and tar but still containing free ammonia, is passed through sulphuric acid which reacts with the ammonia to form ammonium sulphate which is removed and sold.

(8) Final Coolers - a high velocity water spray, coming in direct contact with the gas, further cools it and causes separation of crude napthalene.

(9) Benzol Absorbers - counter-current scrubbing of the gas with "wash oil" results in the absorption of benzol in the "wash oil" and its effective removal from the gas.

a. Stripping Still - by distillation the crude benzol is separated from the "wash oil". After cooling the stripped "wash oil" is returned to the benzol absorbers to pick up another load of benzol.

b. Agitator - to remove resins and other impurities the benzol is agitated with sulphuric acid. The acid is removed by drawing off from the bottom of the agitator. In order to neutralize any excess acid a second wash is carried out with caustic soda. A final wash with water is common practice.

c. Pure Still - a final distillation is made in this apparatus for the fractionization of benzene, toluene, and xylene. Some plants do not separate the benzol into the above fractions but sell a single combined distillate known as "motor spirits".

(10) Gas Storage - gas is conducted to a storage holder. Where the gas is to be used for domestic purposes or in certain chemical plants removal of minor impurities is necessary.

Coke

(1) Quench Tower - the incandescent coke, when rammed out of the retorts, is collected in a special car and transported to a building in which the hot coke is deluged with water.

(2) Sorting & Grading - after cooling, the coke is sorted and graded for size and then goes to storage for eventual sale or plant use.

Ammonia Liquor

(1) Ammonia Liquor Storage - the excess ammonia liquor, separated from the tar and gas in the decanter, is piped to a container for storage.

(2) Ammonia Still - this still is composed of two parts, the free leg and the fixed leg.

a. Free Leg - by distillation with steam free ammonia is driven off in this section of the still.

b. Fixed Leg - by the addition of calcium hydroxide (from quick lime) the chemically combined fixed ammonia is converted to free ammonia.

The latter is driven off by steam distillation. The free leg and fixed leg are not physically separate units but are integral parts of the ammonia still. Phenol recovery methods operate on the weak ammonia liquor before it enters the ammonia still as in the "Benzol Extraction Process" or withdraw the ammonia liquor from the free leg, dephenolize, and return the treated ammonia liquor to the fixed leg as in the "Koppers Vapor Recirculation Process". These phenol recovery processes are discussed more fully under "Phenol Removal and Recovery".

(3) Ammonia Saturators - the free ammonia, liberated in the ammonia still, is absorbed in sulphuric acid to produce ammonium sulphate.

Tar

By-product tar is recovered from the decanter and the tar extractor. The accumulated tar is stored in tanks. It is the practice in some plants to add to the tar thus collected the crude napthalene which is set free in the final cooler. The usual procedure among by-product coke manufacturers is to sell the crude tar to coal-tar refiners. The latter recover phenol, cresylic acid, carbazole, phenanthrene, anthracene, napthalene, pyridine, cumenes, and acenaphthene which are important starting materials for synthetic organic compounds.

Raw Materials and Products

Raw Materials

Table Ck-2 shows the principal raw materials required by a by-product coke plant and the approximate quantities of each as pounds per ton of coal carbonized per day. The character of the coal, the type of retort, and the time and temperature of carbonization each affect the quantity of benzol and ammonia liquor which, in turn, will govern the amount of chemicals needed for their treatment.

Table Ck-2 Raw Materials Used in By-Product Coke Plants

	Sulphuric Acid 66°Be.	Caustic Soda* 95%	Lime**
	Pounds per ton of Coal		
Maximum	28.	0.52	1.8
Minimum	18.	0.23	1.0
Average	26.	0.39	1.3

* Includes only that used in agitator for benzol washing.
** " " " " " converting fixed ammonia to free.

Products

Coke is considered here to be the principal product as such is the case when the by-product coke plant is associated with a steel mill. However, gas may be the product and coke a by-product, as when gas is manufactured for domestic use. The type of coal selected, the carbonization rate (time and temperature), and the retort design will each influence the relative amount of product and by-product. The type of coal selected or the blend of coals used and the regulation of carbonization conditions will be adjusted in any one plant to favor the product from which the greatest profit may be obtained. Table Ck-3 and Table Ck-4 show the quantity of product and by-products usually derived per ton of coal carbonized per day.

Table Ck-3 Products and By-Products from By-Product Coke Plants

Product or By-Product	Unit	Units per Net Ton of Coal Charged	
		Max.	Min.
Coke	lbs.	1525.	1300.
Coke Breeze	lbs.	100.	68.
Tar	gals.	12.	5.
Ammonium Sulphate	lbs.	26.	17.
Gas.	cu.ft.	11300.	10300.
Crude Phenol	lbs.	2.	0.1
Benzene	gals.	2.	1.1
Toluene	gals.	0.5	0.2
Xylene	gals.	0.2	0.1
Napthalene	lbs.	1.2	0.5

Table Ck-4 Average Yield of Coke and By-Products in By-Product Ovens in the United States, 1920-1938. Data from Bureau of Mines.

Product	Unit	Yield of Coke and By-Products				
		1920	1925	1930	1936	1938
		Units per Net Ton of Coal Charged				
Coke	lb.	1395.	1398.	1380.	1409.	1399.
Tar	Gal.	8.2	8.4	9.20	8.86	9.27
Ammonium sulphate or equiv.	lb.	21.4	22.4	23.47	*22.14	*23.36
Light Oil	Gal.	*2.7	*2.9	*3.06	* 2.91	* 2.99
Gas	1000 cu.ft.	10.8	11.2	11.05	11.06	11.04

* Average for plants recovering this commodity.

Coke - The amount of coke produced is roughly 70 percent of the coal carbonized.

Coke Breeze - The dust produced during the coking operation is known as "breeze". The breeze is commonly recovered from the quench water but may be discharged to the sewer in the excess quench water.

Tar - The amount of tar produced is greatly influenced by the coal selected and the time and temperature of the coking operation.

Ammonium Sulphate - is recovered from both the gas and the ammonia liquor. Roughly sixty-seven percent of the total ammonium sulphate is recovered from the gas and the balance from the ammonia liquor.

Gas - like the tar, the quantity of gas varies widely with manufacturing conditions.

Crude Phenol* - the figures shown in Table Ck-3 represent the actual crude phenol recovered, as recently reported by three plants and not the theoretical amount as estimated from analysis of ammonia liquor and ammonia still waste. Phenol is recovered under most circumstances to eliminate taste and odor troubles in downstream water supplies, rather than on account of its value as a by-product.

---

* Includes phenols, cresols, and similar substances.

Benzene, Toluene, & Xylene - The benzol may be fractionated into benzene, toluene and xylene or a single fraction, known as "motor spirits", may be run off and sold.

Napthalene - is usually sold to coal tar refiners as crude napthalene for subsequent purification or it may be added to the tar. In general, it is true that a coal containing a high quantity of volatile matter will yield an increased amount of gas, tar, and benzol, whereas a coal of high fixed carbon content will favor the production of increased quantities of coke. Most ovens use a blend of high and low volatile coals. High oven temperatures reduce the yield of tar and heavy light oils, but increase the benzol yield.

Employees

The ratio of employees to coal carbonized as reported by four plants varied considerably. This variation is open to several explanations.

(1) The degree of purification of the gas will depend upon the purpose for which the gas will be used. Domestic gas requiring a high degree of purification will naturally require more labor in its preparation.

(2) A by-product coke plant, which is a subordinate part of another industry (steel mill or chemical plant), would be expected to have less employees per ton of coal coked than a plant which was entirely independent. As an example, the independent plant might require the services of eight mechanics whereas the coke plant, associated with a larger industry, would be maintained by the mechanical force of the parent organization.

(3) In general, the ratio of employees to coal carbonized per day will probably, other factors being equal, vary inversely as the size of the plant.

A ratio of eight persons per 100 tons of coal coked per day is probably a satisfactory figure for a by-product coke plant producing coke for a steel mill, using the gas for industrial heating, and recovering ammonium sulphate and phenols.

Table Ck-5 Ratio of Employees to Raw Materials in By-Product Coke Plants

Plant	Employees per 100 Tons Coal Carbonized per Day.
A*	20.
B	9.
C	6.
D	7.

* Produced gas for domestic use.

Sources and Quantity of Waste

Summary

Table Ck-6 summarizes the various wastes to be expected from a by-product coke plant and shows the approximate quantity of each to be expected.

Table Ck-6 Quantities of Wastes from Various Sources in By-Product Coke Plants

Waste	Gallons per Ton of Coal Carbonized
Water Carrying Waste Products	
Ammonia Still	22.
Final Cooler	315.
Benzol Carrying	15.
Spent Caustic	small
Cooling Water	3200.
Disposal other than to Sewer	
Quench Water to Atmos.	125.
Spent Sulphuric Acid	small
Pure Still Residue	0.6

Ammonia Still

Table Ck-7 shows the volume of ammonia still waste per ton of coal carbonized. The figures are based on a six months period in 1939. Plant C did not recover ammonium salts and distillation was carried out for the purpose of removing phenol only. Therefore, the volume of ammonia still waste is somewhat less than normal.

Table Ck-7 Volume of Ammonia Still Waste from By-Product Coke Plants

	Ammonia Still Waste - Gallons per Ton of Coal Carbonized			
	Plant A	Plant B	Plant C	Pland D
Maximum	22.	26.	18.	37.
Minimum	16.	17.	15.	32.
Average	19.	21.	16.	36.

Table Ck-8 shows to what extent the ammonia still waste may be expected to vary with the quantity of ammonia liquor. In general, a volume of twenty-two gallons of Ammonia Still Waste per ton of coal carbonized per day may be expected.

Table Ck-8 Relation of Quantities of Ammonia Liquor to Ammonia Still Waste in By-Product Coke Plants

Plant	Gallons per Ton of Coal Carbonized		Ratio of Ammonia Still Waste to Ammonia Liquor
	Ammonia Liquor	Ammonia Still Waste	
A	16.	19.	1.2
B	17.	21.	1.2
C	15.	16.	1.1
D	24.	36.	1.5

Final Cooler

The quantity of water used in the final cooler will vary with the temperature of the cooling water and the volume of gas cooled. Many plants recirculate the final cooler water, thus eliminating this source of pollution. Table Ck-9 gives some idea of the volume of the final cooler waste water in gallons per ton of coal carbonized. An average figure of 315 gallons may be used for rough calculations.

Table Ck-9 Volume of Final Cooler Water from By-Product Coke Plants

	Final Cooler Water - Gallons per Ton of Coal Carbonized			
	Plant A	Plant B	Plant C	Plant F
Maximum	-	-	298.	376.
Minimum	-	-	169.	284.
Average	150.	542.	210.	356.

Benzol Carrying

Direct steam distillation in the stripping, and pure stills of wash oil, and light oil results in a condensate from these units which carry oily substances generally referred to as "benzol". The volume of this "benzol" carrying waste discharged in gallons per ton of coal carbonized is shown in Table Ck-10. The quantity of this waste will depend upon the quantity of benzol in the gas which, in turn, is largely determined by the nature of the coal and the carbonization rate. While the figures presented show considerable variation, a volume of "benzol" carrying waste of 15 gallons per ton of coal carbonized should serve as a representative value for the majority of plants.

Table Ck-10 Volume of Benzol Carrying Water from By-Product Coke Plants.

	Benzol Carrying Waste - Gallons per Ton of Coal Carbonized				
	Plant A	Plant C	Plant E	Plant F	Plant G
Maximum	-	-	-	14	-
Minimum	-	-	-	10	-
Average	40.	14.	5.	13.	12.

Cooling Water

Very limited data indicates the amout of cooling water to be as shown in Table Ck-11. Since the effectiveness of cooling will depend upon the temperature of the cooling water, the volume of cooling water will decrease as the temperature of the cooling water decreases. It is believed that the value of 3,200 gallons is ample and most nearly represents the quantity of water used for cooling in the average coke plant.

Table Ck-11 Volume of Cooling Water from By-Product Coke Plants.

	Cooling Water - Gallons per Ton of Coal Carbonized		
	Plant C	Plant E	Plant F
Average	3200.	3200.	1936.

Light Oil - Caustic Wash

A small amount of spent caustic soda solution is discharged to the sewer during the purification of the light oil in the agitator. Recent data indicates that about 0.4 lbs. of 95 per cent caustic soda is used in the agitator per ton of coal carbonized per day.

Character of Wastes

Summary

Important by-product coke plant wastes come from the ammonia still, the final cooler and from the stripping and pure stills. The ammonia still wastes contain phenol and are often treated for the removal or recovery of this substance. Oxygen requirements are chiefly from the ammonia still and final cooler wastes.

Ammonia Still

The results of analyses made on the ammonia still waste of three plants during 1936 and 1937 are shown in Table Ck-12. The figures are based on averages of daily composite samples taken over a period of eleven to fifteen days. The waste was not treated for phenol recovery or removal.

Table Ck-12 Analyses of Ammonia Still Wastes from By-Product Coke Plants.

Determination	Results in Parts per Million					Average
	Plant E	Plant F		Plant G		
	1936	1936	1937	1936	1937	
B.O.D. 5-day 20°C.	2440	5240	4290	4200	3700	3974
Suspended Solids						
Total	131	626	258	122	647	356
Volatile	84	252	139	65	225	153
Nitrogen						
Organic & NH_3	107	194	274	344	485	281
Organic	79	169	183	260	242	187
Phenol	1360	2320	2790	1640	2170	2057
Cyanide				110		110
pH	8.9					8.9

Final Cooler

Table Ck-13 was prepared from analyses made in 1936 and 1937 of the final cooler effluent of one plant. As in the case of the ammonia still waste, Table Ck-12, these analyses are based on 24-hour composites over a period of twelve days. As already mentioned, recirculation of final cooler water is carried out in many plants. An analysis of the water being recirculated at one plant gave the results shown in Table Ck-14.

Table Ck-13 Analyses of Final Cooler Water from One By-Product Coke Plant (Plant F).

Determination	Results in Parts per Million		
	1936	1937	Average
B.O.D. 5-da.20°C.	115	322	218
Total S.Solids	Less than intake	12	
Nitrogen Org. & NH_3	14	13	14
Phenol	113	98	105

Table Ck-14 Analysis of Final Cooler Water from Closed Recirculating System of a By-Product Coke Plan
Average at Two 24-hour Composite Samples.

Determination	Results in Parts per Million
B.O.D. 5-da. 20°C.	3165
Total Solids	
Total	690
Volatile	368
Suspended Solids	
Total	51
Volatile	23
Nitrogen	
Organic plus Ammonia	227
Ammonia	56
Phenol	1645
K C N	145
Sulphates	130

Benzol Carrying

Waste from the various distillation processes in the purification of benzol when analyzed showed results as in Table Ck-15. The figures shown in this table were based on 24-hour composites averaged over a period of eleven to fifteen days.

Table Ck-15 Analyses of Benzol Purification Wastes from By-Product Coke Plants.

Determination	Results in Parts per Million				
	Plant E	Plant F		Plant G	Average
	1936	1936	1937	1936	
B.O.D. 5-da.20°C	1093.	87.	908.	500.	647.
Suspended Solids					
Total	27.	95.	180.	196.	125.
Volatile	27.	60.	120.	183.	97.
Nitrogen					
Org. & NH_3	27.	28.	23.	4.	20.
Organic	13.	14.	11.	2.	10.
Phenol	6.	6.	264.	12.	72.
pH	6.6	-	-	-	6.6

Combined Wastes

Table Ck-16 was prepared from limited data on the combined by-product coke plant waste effluent, including cooling water, after correcting for the raw water analysis.

Sewered Population Equivalent

Based on Biochemical Oxygen Demand - From Table Ck-17, and using the total volume of waste from each of these three plants, the sewered population equivalent based on the biochemical oxygen demand has been calculated per ton of coal carbonized per day. It is believed that a population equivalent of 15 persons per ton of coal carbonized, based on the biochemical oxygen demand, is a reasonable estimate until more complete information is available. Estimated sewered population equivalents of the several waste producing units are shown in Table Ck-18.

Table Ck-16 Analyses of Combined Waste from By-Product Coke Plants Based on Limited Data

Plant	Nature of Samples	Phenol p.p.m.	Total Susp. Solids p.p.m.	B.O.D. 5-da. 20°C p.p.m.
C	Single "catch" sample	6.4*	Less than intake	96.
E	Av.of 11 daily 24-hr. composites	-	89**	93.
F	Max.for single 24-hr. composite.	-	Less than intake	125.
	Min. " "	-		53.
	Av. of 11 daily 24-hr. composites.	-		76.

* Phenol was reduced at this plant by distillation and coke quenching.

** Included coke breeze.

Table Ck-17 Sewered Population Equivalent of Combined Wastes from By-Product Coke Plants Based in B.O.D.

Plant	Nature of Sample	Sewered Population Equivalent per Ton of* coal carbonized per day
A	Single "catch" sample	17.
B	Av. of 11 daily 24 hr. composites	10.
	Max. for single " " "	15.
	Min. " " " " "	6.
C	Av. of 11 daily 24 hr. composites	15.

* Based on 0.168 pounds 5-day, 20° C. B.O.D. per capita per day.

Table Ck-18 Estimated Sewered Population Equivalents of Waste from Various Sources in By-Product Coke Plants.

Source of Waste	Sewered Population Equivalent B.O.D.* per Ton of Coal Carbonized per Day
Ammonia Still Waste	5.
Final Cooler "	4.
Benzol Carrying "	1.
All other by difference	5.

* Based on 0.168 pounds 5-day, 20°C, B.O.D. per capita per day.

Based on Suspended Solids - Insufficient information is available at this time with respect to the population equivalent based on suspended solids, to assign a value of reasonable worth. One plant showed less suspended solids in the effluent than in the raw water at the intake. This is no doubt partly due to condensate making up a considerable share of the total waste water. A second plant in which coke breeze was wasted to the sewer had a population equivalent of 10 persons per ton of coal carbonized.

Pollution Effects

Oxygen

Oxygen depletion by by-product coke plant wastes, while important, has not caused widespread complaint probably because of the fact that most plants are located on relatively large streams.

Pure Still Residue

Resinous deposits are reported in the vicinity of the outfall from one plant that appeared to be discharging pure still residue to the stream.

Phenols

As is well known, phenols in even small concentrations are detrimental to public water supplies. In higher concentrations phenols are detrimental to fish life. Data on these effects are summarized as follows:-

(1) It has been reported that phenol in quantities of 0.002 to 0.005 p.p.m. in the presence of chlorine will produce medicinal chlorophenol tastes and odors in water.

(2) A concentration of 0.1 p.p.m. of phenol alone imparts to water the characteristic taste and odor of phenol.

(3) Ellis states that in fish "Phenol produces paralysis of the neuro muscular mechanism and hemolyzes the blood." Table 19 shows the results of studies of goldfish in phenol contaminated water.

Table Ck-19 Survival Time of Goldfish in Phenol Contaminated Water

Phenol Concentration in p.p.m.	Survival Time of Goldfish
1000	15 to 30 minutes
100	60 to 72 hours
10	72 hrs. to ∞ *
1	∞ *

* Infinity sign indicates survival greater than four days without apparent injury to fish.

Experiments conducted by Dr. Carl Hubbs, Institute for Fisheries Research, University of Michigan showed (Table Ck-20) that by-product coke plant ammonia still waste, when sufficientl diluted to give values of ammonia and phenol as shown in columns two and three respectively, would produce death in resistant types of fish (Hybcrhynchus notatus) in the time noted in columns three and four. Furthermore, Shelford, Wells, Forbes and Richardson and others found that fish react positively towar phenol - that is, instead of avoiding this pollution, they swim toward higher concentrations.

Table Ck-20 Survival Time of Resistant Fish (Hyborhynchus Notatus) in Phenol-Ammonia Contaminated Water.

Sample No.	Ammonia p.p.m.	Phenol p.p.m.	Time before death Aerated hrs.,min.	Time before death Non-aerated hrs.,min.
2	10.0	4.00	5:02	1:57
	8.0	3.2	100:00	64:15
4	10.0	5.43	4:05	5:35
	8.0	4.43	10:00	10:00
	6.0	3.25	23:35	100:00

Remedial Measures

Summary

By-product coke plant pollution remedial activities have concentrated on the phenol problem. Recovery and removal units with efficiencies of from 90 to 95 per cent are in operation. Oxygen requirements, which have received less attention, can be reduced by about 30 per cent by recirculation and reuse of offending waters.

Recovery Practices

The recovery of by-products may be carried out for either of two reasons: (a) for the profit to be had from their sale; or (b) to eliminate nuisance or other objectionable conditions caused by their discharge into streams.

Ammonium sulphate, crude tar, napthalene, coke breeze, gas, benzene, toluene, and xylene are recovered because of their economic value. One plant producing ammonia compounds synthetically, found it uneconomical to recover the ammonium salts from their by-product coke plant. Information has been received that at least one by-product coke plant is commercially recovering ammonium chloride from the ammonia still waste.

Phenol, while of value, is recovered or removed primarily to prevent chlorophenol taste and odor from developing in downstream water supplies. Under favorable conditions the value of the crude phenol about covers the operating cost of recovery. Phenol recovery and removal methods are discussed in detail later in this guide.

Disposal other than to Sewer

Quench Water - During the quenching operation water is lost to the atmosphere as steam. Data obtained from four plants indicates that the volume lost in this manner is . roughly 125 gallons per ton of coal carbonized per day.

Agitator Acid Waste - Sulphuric acid (66° Be) is commonly used to wash the light oil to remove resins, etc. The amount of acid used in this manner is about 1.6 pounds per ton of coal coked per day and is disposed of by dumping on slag piles.

Pure Still Residue - A residue of about 0.6 gallons per ton of coal carbonized per day remains in the bottom of the pure still after the distillation process. This residue is usually burned.

Miscellaneous Pollution Reduction Practices

Quench Water - The water used to quench the incandescent coke is partially lost to the atmosphere as steam, while the excess water always present may be disposed of in three ways:

(1) Run to waste with the resulting loss of coke breeze (coke dust) and eventual deposition of the breeze in the receiving body of water.

(2) Collection of the excess quench water in a sedimentation basin; recovery of the coke breeze; disposal to sewer of the comparatively clear supernatant liquid.

(3) If the clear liquor from the second method as described above is reused for coke quenching, after adding what fresh water is necessary, a completely enclosed system is the result, with no waste being discharged to the sewer. This system is commercial practice in many plants.

A marked reduction in suspended solids can be expected as the result of changing from method No.1 to method No.3. The cost of additional equipment to reuse water from the sedimentation basins for quenching of hot coke is approximately $3,000.00 per 1,000 tons of coal carbonized per day and the operating cost will be roughly $3.00 per 1,000 tons of coal carbonized per day.

Ammonia Still Waste Liquor - With the exception of phenol and ammonium chloride recovery, the information available at present indicates that no other pollution reduction practices are followed commercially on the ammonia still waste.

Final Cooler Water - A large amount of water (approximately 315 gallons perton of coal coked per day) is used in the final coolers. This water comes in direct contact with the by-product coke gas and thus may carry considerable contamination. Many plants allow the effluent from the final cooler to run directly to the sewer, others recirculate the water through cooling towers. A portion of the recirculated water may be used for coke quenching, making up the loss of final cooler water with fresh water, or the recirculating water may be discharged periodically to streams during high water conditions and the system refilled with fresh water.

Analysis shows the phenol content of the final cooler effluent to be about 100 p.p.m. and the sewered population equivalent per ton of coal carbonized per day to be about 4 persons, based on the biochemical oxygen demand. Thus, by converting the common direct discharge final cooler to a recirculating system, a material reduction in the population equivalent and in waste phenol content may be secured.

The initial cost of a closed indirect final cooler recirculating system is about $25,000 per 1,000 tons of coal carbonized per day and operating costs are approximately $6.50 per 1,000 tons of coal carbonized per day.

The question of atmospheric pollution by hydrogen sulphide vapors is involved in the installation of atmospheric type coolers. A closed indirect cooler does not discharge hydrogen sulphide vapors. However, such a cooler requires removal of naphthalene to reduce stoppages. The atmospheric type cooler is, in general, greater in initial cost.

Benzol Still Waste - Condensate from the various benzol stills is contaminated with wash oil and benzol or light oil. This oily material may be present as oil in water emulsions or as free surface oil. Gravity separators should be, and usually are, employed to remove the free oil. That oil in the form of emulsions is largely wasted to the sewer. Gravity separators can be installed at a cost of approximately $3,000.00 per 1,000 tons of coal carbonized per day.

Agitator Acid Waste - This waste is disposed of by dumping on slag piles in the great majority of by-product coke plants. Methods have been devised whereby this waste is treated with steam to recover the sulphuric acid. The dilute acid thus recovered is suitable for use in the ammonia saturators.

Agitator Alkali Waste - The alkali waste from the agitator is customarily run to the sewer.

Pure Still Residue - This viscous resinous material remaining in the bottom of the pure still after the xylene, benzene, and toluene have been distilled off, is usually disposed of by burning or dumping on slag piles. One plant investigated appeared to be discharging this material to a stream, resulting in resinous deposits in the vicinity of the outfall.

Phenol Removal and Recovery

Methods of treatment may be divided roughly into two classifications:

Removal of phenols and their conversion into non-taste and odor producing compounds which may safely be wasted.

Recovery of phenols as crude phenol or sodium phenolate having some commercial value.

Removal of Phenols

Biological Treatment - Phenols may be oxidized in natural waters, biological filters, or by the activated sludge process to non-taste and odor producing compounds. However, the phenol must not be present in too large quantities, otherwise a toxic effect will be produced on the organism causing the oxidation.

Eldridge states that work by Bach indicated that the phenol content for natural purification must be not over 25 p.p.m. Streeter concludes, from information obtained from operators of municipal water purification plants located along the Ohio River, that phenols are reduced by natural purification, this phenomenon being, in general, made of action similar to that commonly associated with the self-purification of streams.

Eldridge found, in a survey of the literature, a wide difference of opinion as to the amount of ammonia still waste which may be safely mixed with sewage to be treated in an Imhoff tank. A ratio of 1 to 2,000 is suggested by Shindman, the Gas Reseach Committee a 1 to 200, and Sperr states that one part of still waste to 10 parts of sewage may be handled. The phenol is apparently not destroyed by the anaerobic action of the Imhoff tank.

Oxidation process, such as trickling filters and activated sludge, will destroy phenols. Mohlman found that 25 to 30 p.p.m. of phenol may be treated safely on a sand filter and that 30 to 40 p.p.m. by the activated sludge process.

In general, it may be stated that biological treatment of phenolic waste has been found uneconomical for individual by-product coke plants on account of the large treatment area required and the high dilution necessary for satisfactory operation of the biological processes. However, by-product coke plant waste may be run to a municipal sewer and satisfactorily treated, provided there is sufficient dilution of domestic sewage, by activated sludge or on trickling filters. This method provides an economical solution for disposal of by-product coke plant waste at some plants.

Coke Quenching - One of the first commercial methods of treating ammonia still waste was the use of this waste for quenching the incandescent coke. This method has two distinct advantages: (1) complete evaporation of the ammonia still waste, (2) utilization of heat which would otherwise be wasted. On the other hand, there are a number of serious objections to this process; i.e., extensive corrosion of plant equipment by the calcium chloride contained in the still waste; poor appearance and odor of the coke which is not conducive to its sale for domestic use. A flow diagram marked "Phenol Removal System A" is appended which shows the operation of coke quenching with ammonia still waste in a completely enclosed system.

Distillate Coke Quenching - In order to take advantage of the simplicity and cheapness of the coke quenching method of phenol removal, and yet eliminate the high corrosion losses, the following method of treatment was devised by one company.

The ammonia liquor was steam distilled in a regeneration column. The vapor issuing from the still is condensed and run to the quenching pit for use in quenching the coke. It is this distillate which contains the phenols and certain other volatile compounds. The corrosive chlorides remain in the still and are continuously run to waste.

Since the coke is not intended for domestic consumption, difficulty from unpleasant odors, due to the absorbed phenol from the quench water, is not experienced. This plant does not recover ammonium salts.

Table Ck-21 shows the efficiency of phenol removal. The figures shown in the table are averages of weekly composite samples which were analyzed once a week - then averaged for the month. A brief flow sheet is attached to this guide which shows the various operations and their sequence in the distillate coke quenching operation. The diagram is marked "Phenol Removal System B".

Table Ck-21 Phenol Reduction in Ammonia Liquor by Distillate Coke Quenching in a By-Product Coke Plant.

Sources of Wastes	Average Phenol Content in P.P.M.				
	June 1939	July 1939	Aug. 1939	Sept. 1939	Average
Ammonia Liquor	1146.	905.	903.	1255.	1052.
Amm.Still Waste	59.	31.	40.	54.	46.
Percent Removed	94.1	96.0	95.4	95.1	95.1

Recovery of Phenols

The Koppers Vapor Recirculation Process - This system may be described briefly as follows:- Ammonia liquor from the bottom of the free ammonia still is sprayed into the top tower section. It flows down over the wooden-hurdle packing, where it is contacted with a large volume of steam passing counter-current to the liquor. Due to the vapor pressure of the phenol, it passes into the steam. The dephenolized liquor passes, by gravity to the fixed leg of the still. The blower draws the steam from the top of the tower and discharges it into the lower, or caustic section. Here it is scrubbed with a solution of sodium hydroxide, which is added in intermittent shots through the sprays of the lower section. The steam, thus stripped of its phenol, re-enters the top section, completing the cycle.

The caustic soda, in absorbing the phenols, is converted to sodium phenolate. This spent caustic solution flows to the phenolate storage tank. From here it is pumped in batches to the springing tank, where flue gas, rich in carbon dioxide, is bubbled through the solution. The phenols are released from combination with the soda and separated by gravity from the aqueous solution of sodium carbonate formed in the reaction. The sodium phenolate may also be sold directly or "sprung by" any of the other usual agents, such as stack gas, sodium bicarbonate, or sulphuric acid.

In Table Ck-22 is shown the efficiency of this process as operated in two plants. The figures are averages of daily tests in the case of Plant D and in the case of Plant B are averages of about six determinations made during the month.

Table Ck-22 Phenol Removal Efficiency of Vapor Recirculation Process in By-Product Coke Plants.

Source of Waste	Average Phenol Content in P.P.M.					
	April 1939	May 1939	June 1939	July 1939	Aug. 1939	Ave.
Plant B						
Ammonia Liquor	3027.	4784.	4708.	2860.	2774.	3631.
Amm.Still Waste	525.	718.	691.	520.	503.	591.
Percent Removed	78.3	82.0	81.8	79.0	77.0	79.6
	June 1939	July 1939	Aug. 1939	Sept. 1939	Oct. 1939	Ave.
Plant D						
Ammonia Liquor	2706.	2791.	2385.	2276.	2581.	2548.
Amm.Still Waste	150.	171.	166.	166.	205.	172.
Percent Removed	92.3	91.4	90.2	88.8	88.5	90.2

The cost of constructing a unit to recover phenol by the "Vapor-Recirculation Dephenolization Process" will naturally vary with local conditions, with the amount of duplicate equipment required for uninterrupted operation, and the size of the plant as measured by the number of tons of coal carbonized per day. Table Ck-23, however, shows the approximate cost for various size installations.

Table Ck-23 Approximate Installation Cost, Vapor Recirculation Process for Phenol Recovery in By-Product Coke Plants

Tons of Coal Carbonized per Day	Cost of Dephenolization Plant in Dollars
1000 and under	35,000
2000	60,000
4000	101,000
8000	150,000
16000	206,000

The flow sheet marked "Phenol Recovery by Koppers Dephenolization Process" appended to this guide will aid in an understanding of the process.

Benzol Extraction Process - In this process the ammonia liquor is treated for removal of the phenols before the liquor enters the ammonia still, rather than removing the liquor from the free leg of the ammonia still for treatment as in the vapor recirculation process. A flow sheet of this process is attached to this guide. Reference to this diagram will aid in understanding the following description of the benzol extraction process.

Weak ammonia liquor is pumped to the top of No. 1 absorbing tower. The liquor then passes down through beds of egg sized coke, then out the bottom and up to the top of No. 2 absorber. The liquor next passes down through No. 2 absorber. From No. 2 absorber it flows out the bottom and into the dephenolated liquor storage tank.

Against this flow of ammonia liquor is passed motor benzol. The benzol is pumped from the circulating tank to the bottom of No. 2 absorber. It passes into the absorber directly underneath a perforated plate, and, due to the difference in the specific gravity of benzol and ammonia liquor, it passes up through the plate, through the beds of coke, and collects at the top of the absorber. It is then pumped to the bottom of No. 1 absorber, through which it passes in the same manner. During its passage through the slowly moving ammonia liquor, the benzol thoroughly scrubs the liquor and absorbs from it the dissolved phenol.

The phenol laden benzol flows from the top of No. 1 absorber into the bottom of one of the caustic washers after which it passes up through the caustic solution and collects in the space above the caustic level. It is then pumped into the bottom of a second caustic washer. From the top of the second washer it passes to the benzol tank to be recirculated through the system again. While the benzol containing phenol passes through the caustic washers, the caustic soda unites with the phenol to form sodium phenolate.

Liberation of the phenol may be brought about by adding concentrated sulphuric acid to the sodium phenolate to form phenol and sodium sulphate. The latter is wasted to the sewer. The phenol thus produced has approximately the following analysis:

Phenol	54%	(Vol.)
Cresols	23%	
Water	16%	
Tarry Matter	7%	

It may be used without refining in the manufacture of sheep and cattle dips and other crude disinfectants. After refining, it is a source of pure phenol and cresols used in the manufacture of bakelite, antiseptics, dyes and so forth. Table Ck-24 shows the efficiency of this process as operated in one plant.

Table Ck-24 Phenol Removal Efficiency of Benzol Extraction Process in By-Product Coke Plants.

Phenol in	Average Phenol Content in P.P.M.					
	May 1939	June 1939	July 1939	Aug. 1939	Sept. 1939	Ave.
Ammonia Liquor	4950.	6200.	5612.	5958.	5665.	5677.
Amm.Still Waste	125.	140.	68.	50.	52.	87.
Percent Removed	97.1	97.0	98.5	97.8	99.0	97.7

The present tendency in by-product coke plants recovering phenol by either the "Koppers Vapor Recirculation Process" or by the "Benzol Extraction Process" is to sell the sodium phenolate directly to coal tar refiners rather than "springing" the crude phenol at the by-product plant.

Absorption by Activated Carbon - The absorption by activated carbon of phenols has been considered but not applied commercially in this country. Removal of the phenol, after absorption by the activated carbon, has been accomplished with varied success by:

(1) Distillation with super heated steam.
(2) Extraction with benzene.
(3) Extraction with caustic soda.

The process of extraction with benzene has been in commercial use in Germany. Eldridge has attempted the removal of the phenol from the activated carbon by the use of caustic soda solution on a laboratory scale.

Bibliography

(1) Industrial Chemistry, by Emil Raymond Riegel, Ph.D.

(2) Coal Carbonization, by Horace C. Porter, M.S. Ph.D.

(3) International Handbook of the By-Product Coke Industry, by Prof. Dr. W. Glund.

(4) Industrial Chemistry, edited by Allen Rogers.

(5) Private Communication.

(6) Coke Plant Effluent Reports to W.Va. State Water Commission.

(7) Unpublished data U.S.P.H.S.

(8) F.W.Mohlman, Sanitary District of Chicago, unpublished data 1936-1937.

(9) Private communication Eng. & Const. Div., The Koppers Co. March 1, 1940.

(9a) Private communication Semet-Solvay Engineering Corp.

(10) Elimination of Tastes & Odor in Water, by John R. Baylis.

(11) U.S.Dept. of Commerce, Bul. No.22, Detection and Measurement of Stream Pollution, by M. M. Ellis.

(12) Seventh Annual Report, Milwaukee Sewerage Com., 1920.

(13) Report on Sanitary Engineering Projects, Nov. 1933-Nov. 1934, Michigan Engineering Experiment Station.

(14) Chloro-Phenol Tastes and Odors in Water Supplies of Ohio River Cities by H.W.Streeter, Sanitary Engineer, U. S. Public Health Service.

(15) A simple Process for the disposal of Ammonia Liquor, by D.V.Moses and B.H.Mackey, Chem. & Met. Eng., Aug. 1932.

(16) Vapor-Recirculation Dephenolization Process by The Koppers Company, Pittsburgh, Penn.

(17) Elimination and Recovery of Phenols from By-Product Coke Oven Wastes as done at Fairmont, W.Va., by Hugh E. Jones, Proc. of the Third Ann. Conf. on Water Purification, W.Va. Univ., Morgantown.

(18) Disappearance of the "Gas-House District" by A.R.Powell Chem. & Met. Eng. 38:9 1931.

(19) Gas and Coal Products, Chem. & Met. Eng., 47:2 1940.

(20) Files of W.Va. State Water Comm.

(21) Monograph No. 5 U. S. Bureau of Mines.

(22) Bull. Illinois State Lab. Nat. Hist., Vol. XI, Art. VI. March 1917.

(23) Ibid., Vol. XIII, Art. II, Sept. 1918.

(24) Ibid., Vol. XIII, Art. VI, 1919.

(25) Fish Catastrophies During Droughts By G.E.Schaut, J.A.W.W.A., May 1939, p 771-822.

(26) The Problem of Biochemical Decomposition of Phenol in Natural Water by H. Bach, Gesundh Ing., 51:773 1928.

(27) Disappearance of Phenol in Water by H. Bach, Gesundh Ing., 52:796, 1929.

(28) The Removal of Phenol Wastes from Gas Plants by Shindman, Lovis and Bowman; Gas Age Record 61:626, 1929.

(29) Disposal of Liquid Effluents from Gas Works 2nd Rept. Inst. Gas Eng., Gas J., 182;1016, 1928.

(30) Disposal of Phenol from By-Product Coke Plants by F.W.Sperr, J. Am. Public Health 19:901, 1929.

(31) Biochemical Oxidation of Phenolic Waste by F. W. Mohlman, Am. J. Public Health, 19:145, 1929.

(32) Dephenolization of Ammonia Liquor by the Koppers Vapor Recirculation Process by P. J. Wilson, A.G.A., Proc., 1929, p. 934-936.

(33) The Removal of Phenols from Ammonia Liquor at the Troy Coke Plant by Ralph D. Williams, A.G.A., Proc. 1929, p. 937-940.

(34) Removal and Recovery of Phenols from Ammonia Sulphate Still Effluents by D. W. Parkes, J. Soc., Chem. Ind., 46:186, 1927.

(35) Elimination of Phenols from Effluents of Coking Plants by W. Fitz, Asphalt, u, Terr. 30:522, 1930.

(36) Removal of Phenols from Crude Ammonia by Activated Carbon by F. Sierp, Gas u. Wasserfach 76:105, 1933.

BY-PRODUCT COKE PLANT WASTES (Not an actual plant)

lant Consolidated Coke Co. State W. Va. Ref.No. K 623

ity Charleston County Kanawha Main Watershed Kanawha

ddress P.O. Box 13, Charleston, W. Va. Sub-watershed ——————

nformant Mr. John Doe Title Super Principal Product Coke

lant Operation:	Hours per Week	Days per Year	Plant Employees
Average	168	365	330
Maximum	168	365	340

easonal variation None

ATER SUPPLY:	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	City Supply	34,600	36,000	Coag-Sed-Filt-Chlor.
Industrial	Kanawha R.	500,000	700,000	None
Cooling	Kanawha R.	2.5 Mil.	3.0 Mil.	None

OAL PROCESSED DAILY 1,200 Tons

Chemicals: Sulphuric Acid 15.6 T.-26°Be Sodium Hydroxide 468 lb. Lime 1,560 lb.

RODUCTS:- Daily Average: Coke 840 Tons ~~Sodium~~ Phenol~~ate~~ 1,000 lb.

Ammonium Sulfate 12 Tons Tar 9,600 gal. Xylene 120 gal. Benzene 2,400 gal.

Toluene 240 gal. Tar (Shipped as such) 100 % (Processed) 0

ASTES:- Quantity 2.8 Mil. gal. p.d. How estimated metered Supply quench

Character: ~~Washing~~ F. Cooler 378,000 gal. p.d. Quenching 150,000 gal. p.d.

Ammonia still waste 26,000 gal. p.d. Cooling and condensing 2.46 Mil. g. p.d.

Carrying benzol 18,000 gal. p.d. Recirculating None

Disposal other than water carried Spent H_2 Sa_4 & still residue to Slag pile

Possible spills no recent history Type phenol recovery Koppers Vapor Circulat'n

FFLUENT ANALYSES: Number daily Date —— By whom Plant Lab.

P.P.M. Phenol: Ammonia Liquor 3021

Ammonia still wastes 112 Per cent phenol recovered 96.5

UTLET: Where to Kanawha River

Description:	Size and Shape	Material	Location	Elevation
1.	18" Cir.	Tile	East end	Co. Property line
2.	6" Cir.	Cast iron	Rear of	quench tower
3.	6" Cir.	Tile	50' West of	pump house

Gaging possibilities Good - weir in channel from outlets to River

Conditions below outlet: Color Same oils

Turbidity Slight Deposits none

ANITARY SEWAGE: Disposal run to Kanowha Persons tributary 346

EMARKS Quench is completely enclosed Sys. Final cooler water not recirculated. No increase in capacity contemplated.

Survey by Howard Blank Date 3 - 6 - 1940

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an actual plan

River Mileage Index No. K 62.3

Type of Plant By-product coke State W.Va.

Name of Plant Consolidated Coke Co.

Municipality Charleston Main Watershed Kanawha

County Kanawha Subwatershed ——

Address P. O. Box 13, Charleston, W.Va.

Source of Information Mr. John Doe, Superintendent.

Plant Operation:- 168 hrs. p. wk. - 365 da. p. yr.
Employees Av. office 16, plant 330
" Max. office 20, plant 340

Seasonal Variation:- None

(Survey report continued on next page)

Survey by Howard Blank Date March 6, 1940

Sewered Population Equivalent Computation:-

Factors used per ton of coal carbonized per day

B.O.D. 15 Suspended solids ——

Sewered population equivalent* based on B.O.D. 18,000

Sewered population equivalent* based on suspended solids ——

Remarks: Quench is completely enclosed system.
Final cooler water not recirculated.
Koppers Vapor recirculation dephenolization system.

Computation by: M. L. Wood Date 4-15-40. Cincinnati Ofi

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
*Rounded to nearest 100.

Consolidated Coke Co.,
Charleston, W. Va.

Water Supply -
Drinking - from city mains. Av. 34,600. Max. 36,000 g.p.d.
Industrial - Kanawha River. Av. 500,000. Max. 700,000 g.p.d.
Cooling - Kanawha River. Av. 2.5. Max. 3.0 Mil.g.p.d.

Raw Materials -		
	Coal	1200 T.p.d.
	Sulphuric Acid (26° Be)	15.6 T.p.d.
	Caustic Soda (95%)	468 lb.p.d.
	Lime	1560 lb.p.d.

Products -		
	Coke	840 T.p.d.
	Crude Phenol	1,000 lb.p.d.
	Total ammonium sulphate	12 T.p.d.
	Tar	9,600 g.p.d.
	Xylene	120 g.p.d.
	Benzene	2,400 g.p.d.
	Toluene	240 g.p.d.

Napthalene is separated in final cooler and added to the crude tar. Crude tar is sold as such and not refined.

Wastes -		
	Total (from metered supply less loss in quenching)	2.8 mil.g.p.d.
	Final Cooler (not recirculated)	378,000 g.p.d.
	Ammonia Still Waste	26,000 g.p.d.
	Benzol Carrying	18,000 g.p.d.
	Quench water lost to atmos.	150,000 g.p.d.
	Cooling	2.46 mil.g.p.d.

Spent sulphuric acid and residue from pure still are dumped on slag pile or burned.

Phenol is recovered as crude phenol by the Koppers Vapor recirculation process.

Analysis - The attached analyses show an average ammonia liquor phenol content of 3021 p.p.m. and the ammonia still waste contained 112 p.p.m. A recovery efficiency of 96.5%. Analyses are made daily by plant lab.

Outlets - 18" circular tile at east end of Co. property, carrying cooling water, storm water, and sanitary waste.

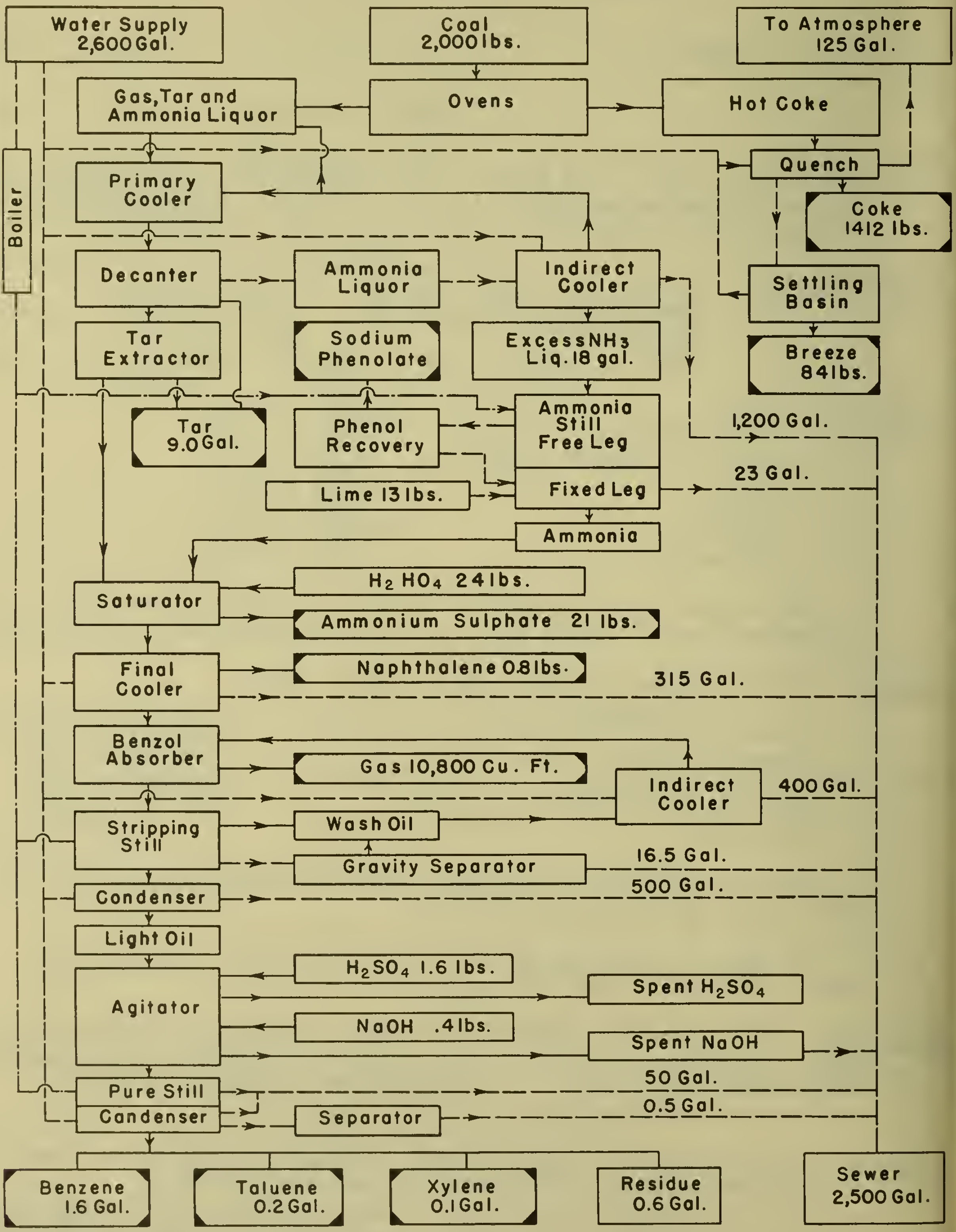
2 - 6" outlets carrying final cooler water, ammonia still waste, and benzol carrying waste, at rear of quench tower and 50' west of pump house. All may be measures by weirs in channel between outlet and river.

Remarks - Company does not contemplate any immediate expansion.

Flow Diagram

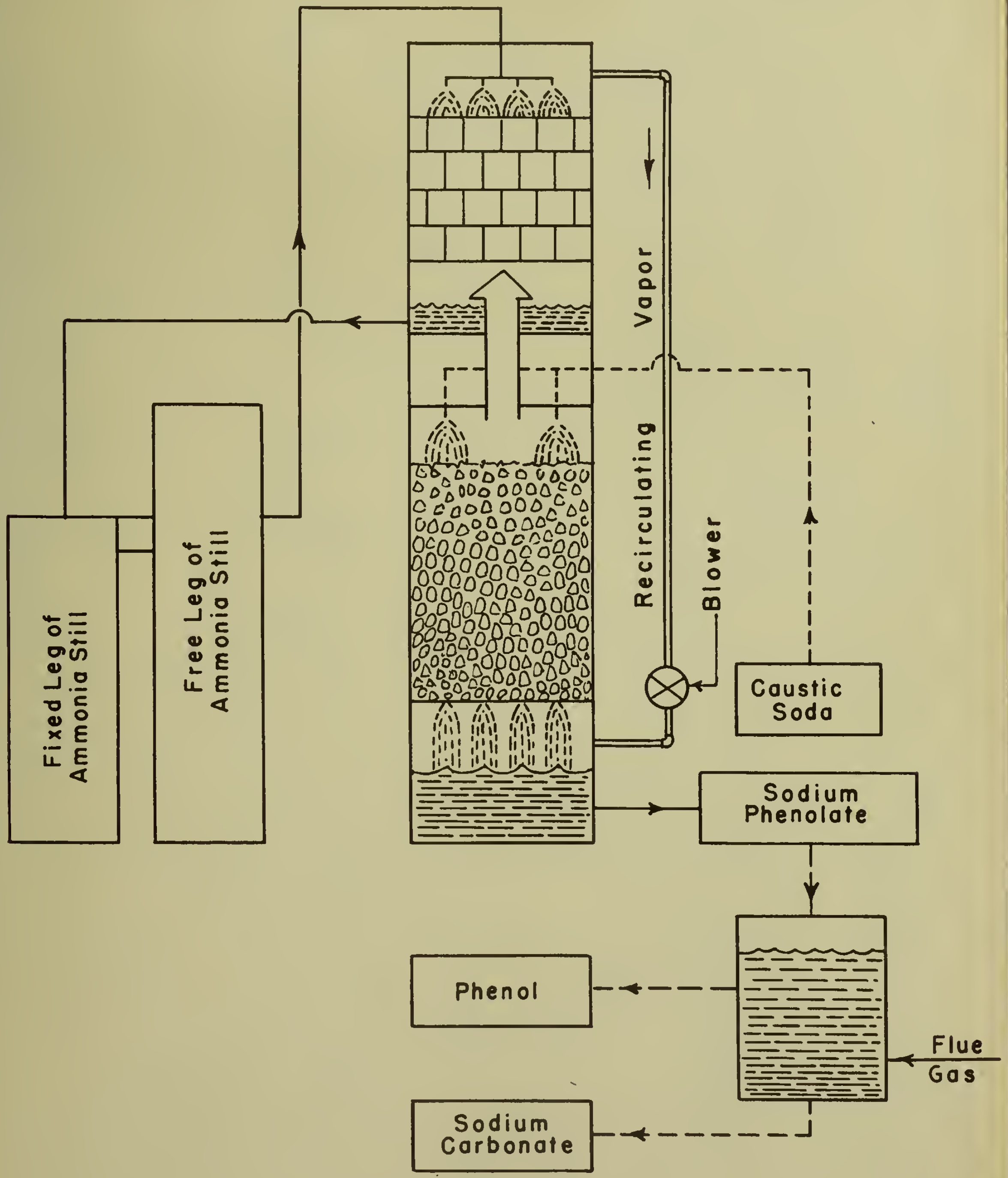
BY PRODUCT COKE PLANT

Direct System of Ammonia Recovery



OHIO RIVER POLLUTION SURVEY
U.S PUBLIC HEALTH SERVICE
OFFICE OF STREAM SANITATION
APRIL-1940

PHENOL RECOVERY
BY
Koppers Dephenolization Progress



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
OFFICE OF STREAM SANITATION
APRIL-1940

OHIO RIVER POLLUTION SURVEY

COTTON

An Industrial Waste Guide to
the Cotton Industry

APPENDIX "V" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract Ct-1
Description of Process Ct-2
Sources, Quantity and Character of Wastes. . . . Ct-11
Remedial Measures. Ct-20
Bibliography Ct-24
Note Taking Form Ct-27
Inspection Report. Ct-28
Flow Diagram Ct-31

List of Tables

Ct-1 Cotton Textile Wastes - Summary of Waste Discharge and Sewered Population Equivalents per 1,000 pounds of Goods Processed per Day, with Typical Analytical Results for Various Cotton Wastes Ct-1

Ct-2 Cotton Textile Wastes - Examples of Quantity, Quality and Sewered Population Equivalents of Various Wastes from the Processing of Cotton, Except Dyeing, with Typical Analytical Results Ct-15

Ct-3 Cotton Textile Wastes - Examples of Quantity, Quality and Sewered Population Equivalents of Various Wastes from the Dyeing of Cotton with Typical Analytical Results. Ct-19

Abstract

Cotton is transformed from the staple to the finished cloth in two general procedures. First, the fabrication of the fiber to fabric and second, the processing of the cloth. It is from the processing of the cloth that the major portion of the liquid waste emanates. Considerable waste may originate from the processing of raw stock and treatment of warp.

Textile wastes are noted for pollutional and chemical strength, toxicity, and tinctorial properties. They are common pollutional offenders and have proven difficult to purify by ordinary sewage treatment facilities. The most polluting wastes are obtained from the deterging and dyeing operations. These wastes are large in volume, strong chemically, and highly polluting.

Table Ct-1 Cotton Textile Wastes - Summary of Waste Discharge and Sewered Population Equivalents per 1,000 pounds of Goods Processed per Day, with Typical Analytical Results for Various Cotton Wastes.

Industry	Wastes, Gallons per 1000 lbs. of Goods	Typical B.O.D. 5-day 20° C. p.p.m.	Sewered Population Equivalent per 1,000 lbs. of Goods Processed per Day (B.O.D.)
Cotton			
Sizing	60	820	2
Desizing	1,100	1,750	96
Kiering	1,700	1,240	108
Bleaching	1,200	300	17
Souring	3,400	72	12
Mercerizing	30,000	55	83
Dyeing			
Direct	6,400	220	71
Basic	18,000	100	100
Vat	19,000	140	130
Sulfur	5,400	1,300	360
Developed	14,400	170	120
Naphthol	4,800	250	59
Aniline Black	15,600	55	41

Typical formulas for each process have been presented, followed by the analyses of the waste produced. Pollutional equivalents shown on Table Ct-1 may be applied to the wastes, affording a means of comparison with domestic sewage, and a method of estimating the pollutional quantity of similar waste from other mills. Composite wastes from a number of cotton mills have been presented. Typical variations occur although a severed population equivalent of 20 per 1,000 gallons of waste appears to be a representative average.

Recovery and re-use of the waste liquors or other pollution reduction measures have lagged although latent possibilities exist. Chemical treatment and equalization of flow, either alone or followed by treatment in a municipal sewage treatment plant, offer the best possibilities for correcting this type of pollution.

Description of Processes

The description of the processing of cotton fiber to the finished product has been subdivided into three general classifications: "fabrication" tracing the raw cotton to thread, yarn or cloth; "deterging" describing the methods by which the material is cleaned, bleached, and finished or prepared for dyeing; and "dyeing" describing some of the coloring practices.

Fabrication

Fabrication comprises processes of "carding", "spinning", "spooling and Warping", "slashing and drawing", "weaving" and "knitting".

Carding Department - Raw cotton as received by the mill has been ginned and compressed into bales of approximately 500 pounds. The bales are opened and the cotton mechanically mixed, and made fluffy. Partial cleaning occurs during the process. Cotton may be dyed in this form called "raw stock dyeing", in preparation for weaving into cloth such as denim (overall material). The raw stock dyeing process will be described later.

The next operations consist of "picking", "carding", "combing", "drawing" and "roving". "Picking" continues the cleaning process, putting the cotton into "laps" of uniform density. The loosely matted layers or laps resemble absorbent cotton. "Carding" changes the cotton lap into a loose untwisted "rope"or "sliver".

"Combing" is performed to produce fine yarns and continues the work of the carding machine by cleaning and combing out the short fibers and tangles. Combing places the fibers parallel to each other. "Drawing" allows 4 to 6 strands of sliver to be combined and "drawn" or "drafted" into a single sliver of the same diameter or weight as those entering the machine. "Roving" is a term denoting the cotton sliver after it has been drafted and reduced in size, slightly twisted and wound on a double bobbin. The machines are usually called "roving frames". Roving may be dyed in this form similar to raw stock dyeing.

Spinning Department - The roving delivered to the spinning frame is drafted or drawn to the required size and twisted to give maximum strength. The twist is imparted to the yarn by the spinning frame. Yarn designed for "filling" (woof, weft, picks, or crosswise threads) is ready for the weaving department when spun on bobbins suitable for use in the loom. Warp threads (ends) undergo further treatment. Material for use in blue denim and similar cloth may be yarn dyed as described under indigo dyeing. Thread and cord is prepared by spinning into the desired line or thread.

Spooling and Warping Department - "Spooling" consists of winding the yarn from a large number of small bobbins onto a large spool that feeds the warper. "Warping" is the operation of winding from 300 to 400 warp ends on a large section beam to be used for weaving. Beamed warp is processed and dyed similar to chain warp.

Slashing and Drawing Departments - "Slashing" is the process of treating the yarn with starch and softeners that aid in weaving and protect the fiber from damage. The materials applied to the yarn are calling "sizing". Drawing-in or tying-in is the method of separating the ends of the warp and drawing them through the drop wires, harness, and reed according to weaving practice. Machines are used to tie-in the warp from the new section beam to the yarn remaining from the old section beam, eliminating the tedious procedure of drawing-in each individual thread.

Weaving Department - The warp beam, after tying-in, is placed on the loom. The loom mechanism, by means of the harness, raises part of the warp threads and lowers the rest, making a V-shaped opening through which the shuttle with the filling or weft thread passes. The position of the warp threads are then reversed and the filling locked into the warp by a forward motion of the reed.

Knitting - Knitting is the making of cloth with only one set of threads by catching one loop into another. The yarn may be carried crosswise to the fabric called weft knitting or lengthwise to the fabric called warp knitting. Weft knitting is used in the making of hosiery and underwear, the important fabrics of cotton knitting.

Deterging

Cloth from the loom is "in the gray" or called "gray goods". Gray goods is the untreated and unfinished cloth probably obtaining its name from the appearance of the material. Many mills produce only gray goods to be finished elsewhere. Such mills generally have negligible amounts of industrial wastes.

Preparing the cloth for market involves many processes such as desizing, scouring or kiering, bleaching, etc., before the goods can be dyed and/or finished. These are the cleansing or deterging operations.

First, the loose fibers are singed and then the sizing that was applied to the yarn is removed. Previous to dyeing, the natural waxy coating is removed from the fiber, allowing increased absorption of dye from the coloring solutions. Should bleaching be necessary, not only the waxy coating, but also impurities on the fiber must be removed. The material may be subjected to other miscellaneous processes prior to the dyeing or finishing procedures.

Singeing or Gassing - Singeing to burn off loose fibers is the first step in the finishing of the cotton cloth. The material is passed rapidly over an open gas flame and immediately dipped into a standing vat of water. Following this, the cotton may receive a "gray wash" which is a preliminary wet-out to remove external dirt, soften the fiber, and remove some sizing.

Desizing - Desizing, the operation of removing the starch sizing that was applied to the yarn prior to weaving, may be accomplished by several methods. Sizing may be removed in the caustic kier boil, a method that is rapidly becoming popular, or in the kier boil after treatment with dilute sulfuric acid. This preliminary acid treatment, called the "gray sour", softens the cloth and removes some of the starch. One of the most common methods of desizing is by steeping in a malt or other enzyme bath for 30 minutes or more followed by an acid treatment or "brown sour". Enzymatic bodies act readily upon the starch converting it to soluble sugars and solubilize the pectin and waxy matter on the fiber. Waste desizing liquors are highly polluting, although the volumes are small.

Scouring or Kiering - The presence of the waxy coating on the raw fiber causes it to be water repellant, hence difficult to impregnate with solutions. Therefore, cotton material must be scoured for dyeing or bleaching to remove the impurities and make the cloth absorbent for the operations that may follow. Scouring consists of boiling in a dilute solution of caustic soda, soda ash, soap or other alkaline substances. Certain oils, such as turkey-red oil (sulfonated castor oil) also have the property of rapidly removing the cotton-wax.

Scouring is usually accomplished by boiling under pressure in an iron kettle called a "kier". Cotton is kiered from 8 to 12 hours at temperatures as high as 125° C. (257° F.) with pressures varying from 10 to 80 pounds. When kiering is not necessary, as in the case of deep colors, the cloth may be lighly scoured by a caustic solution in an open vat. This process is called "wet-out". On the other hand, boiling in a very strong caustic solution in the open vat is called "boil-out". After scouring, the cloth is thoroughly rinsed.

Modern practice tends to simplify procedure by kiering in a single pressure boil and eliminating the desizing and "boil-out" operations.

Kier liquor is the largest single waste from cotton mills and is the most harmful of all the wastes produced in the processing of cloth.

Bleaching or Chemicking - Cotton cloth is bleached extensively for white goods and as a preparation for level dyeing and the dyeing of delicate shades. The material is worked in a cold, dilute solution of chloride of lime (bleaching powder or chemic - $CaOCl_2$) or in a solution of sodium hypochlorite prepared by dissolving chlorine gas in a soda ash or caustic soda solution. The cloth is then squeezed by rollers and exposed to the air. Bleaching is brought about by action of the mild oxidizing agents such as hypochlorite. The bleaching agent breaks down slowly to chloride ion, liberating oxygen which reacts with the coloring matter, destroying the pigment.

Peroxides are also used to bleach cotton, especially when complete decolorization is not essential. This method is required for cotton-wool or cotton-silk mixtures. The reagents may be added directly to the kier bath or may be applied in a second kiering operation. The peroxide bleaching kier boil contains sulfuric acid, sodium peroxide, caustic soda, sodium silicate (a bleach assistant) and a soluble oil. The acid is completely neutralized, reacting with the peroxide and the waste is alkaline. Acid is not required for commercial peroxide bleaching agents bought ready for use. The peroxide method of bleaching is said to be increasing in popularity. The waste is similar to that produced by ordinary kiering.

Souring or white sour is the treatment of the cloth with an "anti-chlor" such as sulfuric acid, sodium bisulfite or sodium hydrosulfite. Following bleaching, the cotton is first rinsed with water, then with the anti-chlor to remove decomposed material produced during bleaching, after which the cloth is thoroughly washed of salts and excess acid. The rinses after the white sour usually contain soap to soften the fiber and bluing should the cloth be bleach finished.

The bleach wastes, including spent bleach liquor, the white sour, and all rinses, are large in volume but seldom offer difficulties when combined with wastes from subsequent dyeing processes.

Finishing - Finishing prepares the cloth for sale. A market bleach, as previously mentioned, must be tinted with bluing to intensify the bleach. In practically all instances, cotton cloth is finished by starching and then calendered (passed between steamed iron rolls) to increase the weight, to effect a good feel, and to improve the appearance by smoothing and polishing the surfaces. The waste produced in finishing is small in volume consisting of excess starch paste wasted at the termination of a run.

Miscellaneous Processes - Mercerizing is the process of subjecting cotton which is maintained under tension to a concentrated solution of caustic soda. The caustic soda reacts with the cotton, increasing the luster, sheen, strength, and affinity for dyes. The cotton is washed while under tension, then treated with dilute acid and washed again. The material is usually bleached after mercerizing. The waste from this process is mainly wash waters since the caustic is seldom dumped. The concentrated caustic bath is often reused elsewhere in the mill or recovered by evaporation or dialysis.

Plisse' or crepe goods are materials produced to give a crinkle effect. This is achieved by printing strong caustic soda on the material either in stripes or squares. The cotton in contact with the caustic soda shrinks causing the characteristic rippling effect of plisse' goods. The material is then washed, treated with dilute acid, and given a final rinse. The wastes are mainly wash waters containing the excess acid washed from the goods.

Sanforizing is the shrinking of cotton by forced contraction of a given length of material. The ribbon of cloth enters a machine consisting of a blanket rotating around a steam drum. The cloth is fed at a given rate, undergoes a steaming and is removed from the machine at a reduced rate. Shrinkage is caused by steaming and the mechanical action of the blanket. There is no waste from the sanforizing process.

yeing

Discussion of the dyeing process has been divided into two ections, one having to do with classification or description f the dyes used and the second having to do with the mechanism f dyeing.

Classification of Dyes - A comprehensive study of dyeing ecessitates a classification of the dyestuffs based upon origin nd chemical make-up or upon their application. The classifica-ion dependent upon origin and chemical make-up is of value. owever, the type of waste may be more readily estimated from he classification according to application of the dyestuff.

In considering origin and chemical make-up, dyes may be lassified as natural organic, mineral or inorganic and manu-actured organic. Natural organic dyes are of importance istorically since they were the forerunners of the present yeing industry. As the classification indicates, they are f natural organic origin found in vegetable and animal matter. hese dyes are expensive although still used when bright, fast olors are required. Among the most common natural dyes are he following: logwood, indigo (mainly replaced by the synthetic roduct), cutch, fustic and cochineal. Mineral or inorganic yes are of minor importance in the textile industry. Many are sed in calico printing but only the following are of importance n the actual dyeing process: prussian blue, chrome yellow, hrome green, and iron buff. Chromium salts are used as evelopers or developing aids and must not be confused with their se as dyes. Manufactured organic dyes include the entire roup of so-called coal-tar dyes and form the most important roup. Among these dyes may be listed: magenta, benzo-purpurine, cid violet, tetrazine, alizarines, anilines, naphthols, sulfurs, tc.

In considering the application of dyestuff, classifications nclude substantine or direct colors, basic dyes, vat dyes, ulfur dyes, developed dyes, naphthol colors and aniline black. rinting, a separate method of applying dyestuff is also dis-ussed.

Substantine or direct colors, as the name implies, have direct affinity for cotton. These dyes are of neutral chemical ture and are soluble in water. Because of their great solubility, rect dyes are "salted out" with sodium chloride or sodium sulfate (lauber's salt) and consequently sometimes are called "salt lors". These dyes are also called "dip dyes" after the process. e waste from direct dyeing is, in most instances, the least polluting of all dye wastes although the solubility of direct dyes make it difficult to remove completely the color from the waste waters. Some direct colors, black in particular, are toxic and may interfere with biological processes.

Basic dyes are the salts of colored bases and are used primarily for their brilliancy. Since cotton does not possess acidic properties, combination with basic dye requires an acid "mordant" to be added to the fiber. A mordant is any substance which, combining with a dyestuff to form an insoluble compound or color lake, serves to produce a fixed color in a textile fiber. Tannic acid is readily absorbed from solution by cotton and forms color lakes with basic dyes making it a suitable mordant in this connection. Following the boil-out, the cotton is saturated with tannic acid and to prevent the tannic acid from dissolving in the dye bath, an insoluble antimony tartrate is formed by treatment with tartar emetic. Acetic acid (leveling agent) is added with the dye to retard dyeing, producing a more even shade. An oil and soda ash finishing bath completes the treatment. Five wastes are usually produced during the basic dyeing process.

Vat dyes are so-called because they are applied in a dye bath or "vat" in which the dye is reduced to a soluble form. The dyes are insoluble in water but yield products on reduction by strong reducing agents, such as hydrosulfite, that are soluble in alkaline liquors. Vat dyes are characterized by great fastness to light, washing, acids, alkalines, and many to bleaching. The material to be dyed is immersed in a vat containing the dye, reducing agent, and alkali, and then oxidized either in the air or by soluble oxidizing compounds such as perborate of soda. The goods are "soured" to neutralize any remaining alkali. Each treatment is followed by a rinse. There are three distinct processing wastes: the dye liquor, the "sour", and oxidizing solution, if used. Vat dye wastes are very alkaline and have a high chemical oxygen demand. These wastes are polluting in character.

Sulfur dyes belong to the general group of substantine dyes but, as the name implies, consist of sulfur compounds used with the addition of sodium sulfide. It is not known whether the sodium sulfide acts as a reducing agent, dye solvent or combines with the dyestuff to form a soluble compound. With sulfur black, sodium sulfide acts as a solvent. A neutral salt is added during the process to salt out more of the dye. Sulfur colors are remarkable for their fastness to washing and to acids in "cross dyeing". Sulfur dyes are inexpensive and furnish deep heavy shades on cotton. The waste, consisting of the dye bath and rinses, is very alkaline, highly colored, extremely toxic, and is one of the most polluting dye wastes.

Developed dyes are colors converted or built-up on the fiber. The original dye is a direct color and is applied in a fashion identical with direct color dyeing. The absorbed color is changed to a chemically unstable form by treatment with nitrous acid formed by sodium nitrite and either hydrochloric or sulfuric acid. The unstable azo body is next converted to a stable dyestuff by a developer, usually beta-naphthol. Developed colors are also called "insoluble azo" or "diazotized and developed" from the process, "ice colors", since ice is used to obtain the cold temperature in making the dye and "ingrain colors" as the color is formed within the fiber. They are often classified with naphthol dyes as "color made on the fiber". The developing process increases the fastness of the colors to washing and acids and also increases the intensity of the shade. Three main wastes are produced: the dye bath, the diazotizing bath, and the spent developing bath. Rinses follow each operation and usually a final salt rinse or soap treatment is given the dyed material.

Naphthol colors are produced by reversing the operations of developed dyeing and likewise are azo dyes built on the fiber. The cotton is first treated with a developer as beta-naphthol and then with a diazotized dye bath where the color is developed on the fiber. Naphthol dyes are fast to an extent surpassed only by vat dyes. Most are fast to soaping, washing, and light, while many resist bleaching by chlorine. Two major wastes are produced: the beta-naphthol and the diazotized dye liquors. A hot soap and soda bath is used for after-treatment, brightening the colors and deepening the shades. Six wastes are usually produced including the rinses.

Aniline black is produced on the fiber by the oxidation of aniline hydrochloride. The color itself is an insoluble black pigment produced by the oxidation of aniline. In practice, a mixture of aniline hydrochloride and an oxidizing agent such as potassium chlorate, potassium ferrocyanide, or copper sulfide is applied to the material or printed on the cloth. The subsequent drying and ageing processes produce conditions suitable for the oxidizing action that forms the black pigment. Aniline black is extensively used in calico printing and hosiery dyeing. It is exceptionally fast to light, bleaching, and washing. Aniline black is rather expensive and the original bath is seldom dumped except at the end of long runs. The wastes are from the washing operations where the cloth passes through several vats; for example, one chrome bath, three plain rinses, and then three soap washes followed by two plain rinses.

Mechanism of Dyeing - Dyeing machines are of two general types, one, allowing the material to pass through the dye vat and the other, circulating the dye liquor through the material. Raw stock and roving commonly are dyed by circulating the dye liquor through the material. Sulfur dyes are used extensively. Yarn and chain warp most frequently are dyed in machines allowing the material to pass through the dye vats. An exception is the recent development of dyeing yarn on spools or "cops" by pumping the dye liquor through the material which is wound on perforated tubes.

Of special interest is the dyeing of chain warp with indigo using machines constructed solely for this purpose. The yarn first enters a box containing a hot, caustic solution and is then rinsed. Several vats of reduced indigo follow. After each indigo bath, the yarn is carried over many reels, exposing it to the air causing oxidation of the reduced compound. The colored yarn is washed and finally passed through a softening bath containing a mixture of oils and waxes. The dye vats are rarely dumped, the waste being produced by continuous overflow from the wash boxes.

Piece goods are dyed by passing the cloth through the dye bath. The continuous process is similar to the chain warp method and produces the same wastes; i.e., overflow from the wash boxes. For matching shades or for dyeing small quantities of goods, a machine called a "jig" is used. Briefly, a jig consists of a vat with rollers allowing cloth to pass from one roll down through the dye bath and up onto another roll. This procedure, called "jigging", is repeated until the proper shade is obtained. Customarily, the bath is dumped after each roll of goods is dyed. Some mills using sulfur black dyes retain the vat, make up to strength, and reuse. The cloth is treated and rinsed in the same machine, using large volumes of water. The waste is voluminous and highly polluting, especially when sulfur dye predominates.

Hosiery is dyed in machines similar in appearance and operation to laundry washing machines. Capacities vary from 50 to 300 pounds. Customarily, hosiery is processed on a batch basis; all processes taking place in the same machine.

Stripping and redyeing or reworking is the process of redyeing material when the original color does not meet specifications. It is estimated that from 1 percent to 10 percent of the material in hosiery mills may be reworked. The color is removed or stripped by a bath consisting of soda ash and sodium hydrosulfite followed by a boil-off with soap. Other chemicals may be used in the stripping bath, dependent upon the type of dye. The material is rinsed and then redyed according to mill practice. A strong pollutional waste is discharged by this process.

Tinting is a light shade applied to cloth, yarn, or thread, primarily to distinguish types of material in the mill. This color must be readily removable or easily covered so the choice falls upon direct dyes. The amount of dye in the bath is small and the waste negligible.

Union dyeing is the dyeing of union material composed of cotton and wool or cotton and silk. The wastes will depend upon the type of dyeing. Direct dyes are used for union goods of cotton and wool.

Ingrain is a term usually applied to hosiery when the yarn is dyed prior to knitting.

Printing - Textile printing differs from dyeing since the color is applied to certain portions of the material producing designs or patterns. The dye is applied in a paste of starch, dextrin, or various gums. A single engraved roll is used to apply each color. The engraved depression receives the colored paste from the dye box, the excess being scraped off by a blade (doctor), and prints the color onto the cloth by pressure between a rubber covered roll. The cloth is steamed to fix the color and prevent spreading. The starch paste may then be washed out, leaving the color in the desired pattern. This description is very brief since there are as many, if not more, variations to printing as there are dyes. There are no wastes from the printing machines and only small amounts from the washing of the cloth. The largest portion of the waste is from the color shop (called color shop waste) where the printing pastes are made. The waste consists of washings from color boxes, rolls, tubs, floors, and excess paste and starch. Large volumes of water are used. A new type of dye similar to paint has appeared on the market. The color is mixed with a titanium pigment and printed on the cloth. No washing is necessary, simplifying printing procedure.

Sources, Quantity, and Character of Wastes

It is from the processing and dyeing of textile fabrics that liquid industrial wastes are produced. The dye waste from the carding department consisting mainly of dirt, leaves, sticks, and fragments of the cotton boll is small in volume and unimportant.

Sizing Bath - Slasher Waste

A typical bath consists of 100 pounds of starch and a few pounds of softener per 100 gallons of water. Sizing is applied on the basis of about 60 pounds per 1,000 pounds of goods. No waste is produced except the small amount dumped at the end of a run. A waste is also obtained from the starch kettles which are washed each week. Some examples of slasher wastes are show on Table Ct-2. The wastes from the starch kettles (a) represen results on 2,000 gallons of waste used in sizing approximately 210,000 pounds of material. The wastes from the slasher machin (b) represents results on 1,012 gallons of waste used in sizing approximately 40,000 pounds of material. The waste resulting from sizing is independent of the amount of goods processed, therefore a sewered population equivalent figure based upon 1,000 gallons of waste per day is presented. The average daily discharge may be obtained from which can be calculated the total population equivalent. The sewered population equivalent figure of 2 per 1,000 pounds of product per day is given for purposes of comparison and indicates that the wastes are not greatly significant.

Desizing Bath

The malt or enzyme steeping bath is the only true desizing waste since sizing removed in the kier is included with the was kier liquor. A preliminary acid treatment, the gray sour, is small in volume and has a negligible pollutional quality. The desizing bath waste may have a B.O.D. over 8,000 p.p.m. althoug again the volume is small. The volume of wash water varies wit individual mills but gives a sewered population equivalent approximating 96 per 1,000 pounds of goods per day, as shown in Table Ct-2.

Scouring or Kiering

There are a great many variations in mill procedure for scouring cotton. Raw cotton may be kiered and bleached in one process in one machine while cotton cloth is usually kiered in one process, bleached in another and finally soured. Peroxide bleaching is an exception in which case peroxide is added to th kier combining the two processes. In general, it is observed that the strength of waste is dependent upon the degree of treatment which varies with the strength of the kier bath. Although similar kier wastes produce sewered population equivalents that are strikingly close, the wash waters do not check very well.

There are two methods of kiering cotton cloth: the one-boil and two-boil methods. It has been found that more than 50 percent of all cotton cloth is kiered by the one-boil method. Analytical results covering the four following examples are shown on Table Ct-2:

(a) Boil-off Hosiery - 2% soap, 1% trisodium phosphate.
(b) Boil-off Knit Goods - 2% detergents.
(c) Kiering - one boil - 2.5% sodium hydroxide, 2.0% sodium carbonate. Boil five hours followed by rinsing
or
3.6% sodium hydroxide, 0.4% sodium silicate, 0.3% trisodium phosphate. Boil five hours followed by rinsing.
(d) Kiering - two boil -
First boil - 1.00% sodium hydroxide, 0.40% sodium silicate, 0.15% trisodium phosphate. Boil six hours.
Second boil - 0.50% sodium hydroxide, 0.40% sodium silicate, 0.15% trisodium phosphate. Boil five hours followed by rinsing.

Variations in the population equivalent of the wastes are influenced by the type of kier illustrated by their formulae. The waste from the kier using formula (a) is a light scour previous to dyeing, (b) waste is somewhat stronger while (c) and (d) illustrate the more common kier liquors and will approximate the average waste with a B.O.D. (5-day, 20°C.) of 7,000 to 9,000 p.p.m. and a sewered population equivalent of about 110 per 1,000 pounds of goods per day.

Bleaching or Chemicking

A number of chemicals are used to bleach cotton. Chlorine compounds (chlorine or calcium hypochlorite) are the most common at present although the use of peroxide is rapidly increasing. The cloth is worked cold in an 1.5 to 2° Tw. solution of chloride of lime (bleaching powder or chemic) comparable to 2 percent chlorine solution.

Table Ct-2 shows two examples of chlorine bleach waste with an average B.O.D. (5-day,20° C.) of 300 and a sewered population equivalent of 17 per 1,000 pounds of goods per day.

Souring

After bleaching, the cloth is soured by acid (sulfuric or hydrochloric) of approximately 1° Tw. or by sodium bisulfite of 1 to 1.5 percent. Two samples of sour waste using 1 percent bisulfite giving results indicated on Table Ct-2 showed an average B.O.D. of 72 p.p.m. and a sewered population equivalent of 12 per 1,000 pounds of goods per day.

Kier and Bleach Waste

Raw cotton may be kiered and bleached in one process as previously mentioned. The process usually occurs in one machine in the following order: - (1) Boil-out or wet-out, using caustic soda with a soluble oil, (2) rinsing, (3) bleaching, using soda ash and chlorine gas forming the sodium hypochlorite, (4) sour, using sodium bisulfite or sulfuric acid, and (5) rinsing. The average, shown on Table Ct-2, of results from several samples, each varying only slightly from the average indicated a sewered population equivalent of 71 per 1,000 pounds of goods per day. As stated, the strength of waste is dependent upon the degree of treatment or strength of the bath. The fact that this figure is less than that given for kiering alone indicates a lighter treatment is involved.

Combined Wastes

Many of the kiering, bleaching, souring, and dyeing processes are combined to produce a single waste. Table Ct-2 shows several types of waste analyzed by individual components and then combined to illustrate composite wastes. Of special interest are the boil-off and bleach wastes, both with clorine and peroxide. The chemicals and other materials used in connection with operations producing these wastes are as follows:

Hosiery Mill:-
(a) Boil-off: 2% soap, 1% trisodium phosphate.
(b) Dye: 0.33% dye, 12% salt, 5% oil.
(a') One bath waste, scour and dye: 5.5% scour oil, 9.0% salt, 0.35% dye.
(a'') Boil-off, chlorine bleach: 3% soap, 1.5% trisodium phosphate, 10% chlorine bleach powder.
(a'") Boil-off, peroxide bleach and dye: 2.5% soap, 2.5% peroxide, 3.5% oil, 5.3% salt, 0.025% dye.

Table Ct-2 Cotton Textile Wastes - Examples of Quantity, Quality and Sewered Population Equivalents of Various Wastes from the Processing of Cotton, Except Dyeing, with Typical Analytical Results.

Waste	Flow Gal. per 1,000 lbs. Goods	QUALITY					Sewered Population Equivalent (B.O.D.)	
		Color	pH	Total Solids		B.O.D. 5-day 20° C p.p.m. (1)	Per 1,000 Gal. Waste per day	Per 1,000 lbs. Goods per day
				p.p.m.	lbs. per 1,000 lbs. Goods			
Sizing Bath - Slasher Waste								
(a) Starch Kettles	95	-	-	-	-	620	31	3
(b) Slasher Machine	25	-	-	-	-	590	29	1
(c) Slasher Waste	-	1,000	-	-	-	1,254	62	-
(d) Average	60	-	-	-	-	820	41	2
Desizing Bath								
(a) Desizing Bath	140	-	-	-	-	8,000	-	54
(b) Wash Waters	200 to 1,800	-	-	-	-	840	-	42
(c) Total	1,100	-	-	-	-	1,750	-	96
Scouring (Boil-Off) or Kiering								
(a) Light Scour	3,910	-	8.6	1,300	42	350	-	68
(b) Moderate Scour	1,140	-	9.9	4,100	39	1,450	-	82
(c) Average	1,160	-	-	9,400	89	1,650	-	97
(d) Average	2,320	-	-	6,500	127	1,020	-	120
Average (c & d)	1,740	-	-	8,000	108	1,240	-	108
Bleaching Waste								
(a)	1,230	-	-	-	-	325	-	20
(b)	1,080	-	-	-	-	270	-	14
(c) Average	1,150	-	-	-	-	300	-	17
Souring Waste								
(a)	3,690	-	-	-	-	52	-	10
(b)	3,030	-	-	-	-	92	-	14
(c) Average	3,360	-	-	-	-	72	-	12
Kiering and Bleaching Waste								
(a) Average	11,500	-	-	-	-	120	-	71
Hosiery Mill								
(a) Boil-off	3,910	130	8.6	1,300	42	350	-	68
(b) Dye	5,600	525	7.6	3,900	183	290	-	80
(c) Combined	9,510	330	8.1	2,800	225	310	-	148
(a') One Bath Waste - Scour and Dye	8,570	3,000	9.4	4,630	331	210	-	89
(a") Boil-off Chlorine Bleach	11,150	120	8.9	1,190	111	360	-	200
(a'") Boil-off - Peroxide Bleach and Dye	15,930	1,500	7.9	1,810	241	410	-	324
Knit Goods								
(a) Boil-off	2,460	450	12.2	8,830	181	1,770	-	217
(b) Bleach Waste	1,230	40	10.0	11,360	117	325	-	20
(c) Sour	3,690	20	7.2	1,090	34	52	-	9
(d) Combined	7,380	-	-	5,400	332	670	-	246
(ab') Boil-off and Bleach	1,890	-	9.6	12,300	194	1,020	-	96
(a') Boil-off	1,140	-	9.9	4,100	39	1,450	-	82
(b') Bleach	1,080	-	9.7	16,140	145	270	-	14
(c') Sour	3,030	-	7.2	1,140	30	92	-	14
(d') Dye Waste	1,080	-	8.0	2,150	19	55	-	3
(e') Combined	6,170	-	-	4,600	237	370	-	113
Finishing Waste								
(a)	6	2,500	-	22,000	1	1,250	62	0.4
(b)	-	-	-	-	-	-	152	-
Mercerizing								
(a)	30,000	-	-	-	-	55	-	83

(1) In certain cases, particularly average and combined results, B.O.D. results in parts per million have been computed from sewered population equivalent and flow data reported.

Knit Goods:-

- (a) Boil-off: - 2% detergents, 2% peroxide.
- (b) Bleach waste: - 2% chlorine solution for one hour.
- (c) Sour:- 1% sodium bisulfite solution.
- (ab') Boil-off and bleach:- not recorded.
- (a') Boil-off:- 2% detergents.
- (b') Bleach:- 1.5% chlorine solution for one hour.
- (c') Sour:- 1% sodium bisulfite solution.
- (d') Dye Waste:- 0.05% dye, 2% salt, 2% leveler.

Finishing Waste

The finish applied to cotton is usually starch, waxes, or gums applied as a paste. No waste is produced except the excess discharged at the end of a run. One mill processing 100,000 pounds of cotton per week wasted only 116 gallons per day with the characteristics shown on Table Ct-2. Since the waste is independent of the goods processed, the population equivalents have been based upon the gallons of waste produced. The sewered population equivalent of 0.4 per 1,000 pounds of goods per day is shown for purposes of comparison and indicates that the wastes are not significant. Waste (b) appears to be more representative and gives a more reliable figure. The B.O.D. of waste (a) is probably below the average.

Miscellaneous Processes

Mercerizing of cotton cloth is brought about by treatment with 40 to 60° Tw. (roughly 15-30%) caustic soda while the cotton is under tension. The waste consists of wash waters since the caustic bath is rarely dumped. This includes rinses following caustic treatment, several rinses after souring and possibly an ammonia treatment. The data shown on Table Ct-2 indicating a sewered population equivalent of 83 per 1,000 pounds of goods per day was obtained by averaging wastes produced by mercerizing chain warp and skein cotton yarn.

Plisse' or Crepe - The strong caustic soda used to produce the crinkle is not dumped. The acid rinse and soap and water rinses cause most of the waste which may be slightly acid. Large volumes of water are used. No detailed analyses are available. It is believed that the waste produced by this process is similar to that from mercerizing both in volume and sewered population equivalent.

Dyeing

Direct - Cotton is usually scoured and bleached before dyeing. A wet-out with water or soluble oil is included with dyeing as noted in the formulas. Varying practices produce similar pollutional quantities regardless of the volumes of water. However, it is difficult to correlate the population equivalents to the poundage when dyeing chain warp and cotton cloth by the continuous process. A general direct dye formula is as follows: dye, 0.1 to 10 percent and salt, 3 to 40 percent, followed by rinsing. Comments and explanations on the direct dye waste results shown on Table Ct-3 are as follows:-

Direct Dye Formulas: -
- (a) Hosiery: 0.14% dyestuff, 2% oil, 4% common salt or 10% glauber's salt (sodium sulphate), average of 10 formulas.
- (b) Hosiery: without accessory chemical, formula not reported.
- (c) Cloth: average of several samples, formula not reported.
- (d) Hosiery: 0.33% dye, 12% salt, 5% oil.
- (e) Hosiery: 0.35% dye, 9% salt, 5.5% oil sour, not preceded by scouring.

Direct Black Formula:-
- (a) Average of 3 formulas: 6% dye (4 to 8%), 2% oil, 25% salt, 2% formaldehyde, 0.5% acetic acid, 3% soap, 1% soda ash.

Table Ct-3 shows sewered population figures per 1,000 pounds per day for direct dye waste to vary from 47 to 92, the average figure being 71, the figure for direct black based on three results is much higher or 133. Direct black does not produce true deep shades so an added treatment of formaldehyde and acetic acid is used to increase the fastness of the dye to washing while a soap and olive oil treatment gives the black a deeper and more lustrous tone.

Basic Colors - Basic dye formulas cover the following ranges:

Boil-out bath: 4% S.C. oil, 1.5% Pine Oil.
Tannic acid bath: 1% to 6% tannin.
Tartar emetic bath: 1% to 4% tartar emetic.
Cold wash:
Dye bath: 0.9% dye, 2.5% acetic acid.
Finishing bath: 1% oil.

A wide variation in results of studies of wastes from basic color dyeing is obtained, probably caused by differences in the boil-out. It may be assumed that the low sewered population equivalent value (b), shown on Table Ct-3, of 25 per 1,000 pounds of goods per day is for a weak dye bath while the sewered population equivalent of 340 includes a strong boil-off. It is believed that the sewered population equivalent of an average basic dye waste will range from 50 to approximately 100 per 1,000 pounds of goods per day. The average of 100 indicated on Table Ct-3 and obtained by giving the high result (a) only one-half the weight of the other two results is high for a typical basic dye waste.

Vat Dyes - Vat dye formulas fall within the following ranges: 2-10% dye powder, 6-30% NaOH (76° Tw.), 2-7% hydrosulfite powder concentrated. An average waste, as indicated on Table Ct-3 has a sewered population equivalent of 129 per 1,000 pounds of goods per day.

Sulfur Colors - Formulas for sulfur colors are as follows:-

Range: 1 to 20% dye, sodium sulfide 1 to 4 times weight of dye, 4 to 7% sodium carbonate, 20 to 50% salt.
Average: 7.8% dye, 11.1% sodium sulfide, 4.1% sodium carbonate, 21.6% sodium chloride.

Table Ct-3 indicates a sewered population equivalent of about 360 per 1,000 pounds of goods per day for sulfur color dye waste.

"Jig" waste from jig dyeing with sulfur black gave a much higher sewered population equivalent of 1,780 per 1,000 pounds of goods per day.

A sulfur black hosiery dye formula is as follows: 8% dyestuff, 8% sodium sulfide, 2% sodium carbonate, 10% sodium chloride, 3% mineralized olive oil or soap. The reason for the relatively low sewered population equivalent of 115 per 1,000 pounds of goods per day given on Table Ct-3 is the customary hosiery mill practice of saving the original dye bath. The used dye bath is made up to strength and reused.

Developed Colors - The same general dye formula indicated for a direct dye bath is used. Formulas for later treatments are as follows:

Diazotizing bath: 1.5 to 2.5% sodium nitrite, 3.0 to 5.0% sulfuric acid.
Developing bath: Usually 0.45 to 0.90% beta naphthol or 0.35 to 0.70% phenylene-diamine powder.

Table Ct-3 Cotton Textile Wastes - Examples of Quantity, Quality and Sewered Population Equivalents of Various Wastes from the Dyeing of Cotton with Typical Analytical Results.

	Waste	Flow Gal. per 1,000 lbs. Goods	QUALITY					Sewered Population Equivalent (B.O.D.) per 1,000 lbs. Goods per Day
			Color	pH	Total Solids		B.O.D. 5-day 20° C p.p.m. (1)	
					p.p.m.	lbs. per 1,000 lbs. Goods		
	Direct Dye Waste							
(a)	Hosiery	5,250	-	7.4	1,900	83	270	70
(b)	Hosiery	6,000	-	8.0	1,300	64	160	47
(c)	Cloth	3,600	-	-	-	-	510	92
(d)	Hosiery	5,600	600	7.5	3,900	183	290	80
(e)	Hosiery	8,570	3,000	9.4	4,600	331	210	89
(f)	Average (a) to (e)	6,400	-	8.1	2,600	140	220	71
	Direct Black Waste							
(a)	Average of 3	10,000	-	-	5,900	490	260	133
	Basic Color Wastes							
(a)	1/2 Wt. in Ave.	26,000	-	-	870	188	260	340
(b)		8,300	-	-	1,000	70	60	25
(c)		23,000	-	-	830	159	50	57
(d)	Average	18,000	-	-	900	130	100	100
	Vat Dye							
(a)	Vat Liquor	18,900	-	-	-	-	140	129
	Sulphur Colors							
(a)		5,450	-	-	-	-	1,300	357
	Sulphur Black							
(a)	Jig	17,380	-	-	-	-	2,000	1,780
(b)	Hosiery	5,400	-	-	4,300	194	430	115
	Developed Colors							
(a)	Raw Cotton	8,950	-	-	-	-	210	100
(b)	Spool Cotton	10,350	-	-	-	-	230	119
(c)	Beam Warp	13,250	-	-	-	-	190	128
(d)	Skein Cotton	25,200	-	-	-	-	100	130
(e)	Average	14,400	-	-	-	-	170	120
	Naphthol Colors							
(a)	Naphthol	5,600	-	-	-	-	75	21
(b)	Naphthol (Jig)	3,900	-	-	-	-	500	96
(c)	Average	4,800	-	-	-	-	280	59
	Aniline Black - Wash Waters							
(a)	Continuous	8,300	-	-	-	-	60	25
(b)	Process	23,000	-	-	-	-	50	57
(c)	Average	15,600	-	-	-	-	55	41
	Printing							
(a)	Color Shop	8,050	-	-	-	-	60	23
(b)	" "	1,050	-	-	-	-	130	7
(c)	Average	4,500	-	-	-	-	95	15
	Raw Stock Dyeing							
(a)	Developed Colors	8,950	-	-	-	-	220	100
(b)	Combined Dye House	7,400	-	-	-	-	280	104
(c)	Sulphur incl. Black	4,730	-	-	-	-	1,400	334
	Yarn Dyeing - Indigo							
(a)	Indigo	9,420	900	9.8	-	-	175	82
(b)	"	2,340	-	-	-	-	620	72
(c)	"	660	3,500	10.5	-	-	600	20
	Stripping and Redyeing							
(a)	Hosiery	13,200	-	-	-	-	520	345

(1) In certain cases, particularly average and combined results, B.O.D. results in parts per million have been computed from sewered population equivalents and flow data reported.

Sewered population equivalents shown on Table Ct-3 average 120 per 1,000 pounds of goods per day.

Naphthol Dyeing - The formulas used in the operations of naphthol colors are as follows:

Naphthol bath: 0.25 to 2% NaOH, 0.25 to 2% naphthols.
Dye bath: 0.25 to 2% dye base, 1 to 3% HCl, 1.5% Na_2N, 1.0% sodium acetate, 0.5 to 2% acetic acid and up to 40% salt.
Caustic rinse: 1 to 3% soap, 0.5 to 2% Na_2CO_3, 0.5% NaOH.

Remedial Measures

Cotton textile waste remedial measures may involve waste reduction measures in the textile plant, recovery practices, equalization of flow, particularly of batch discharges, mixture of waste to secure mutual precipitation, treatment in independent textile waste treatment plants, treatment with sewage in municipal plants and practically any combination of these measures.

Reduction Measures

A promising and logical procedure for relieving or eliminating waste pollution or waste treatment consists of preventing the production of wastes. There are important and economic possibilities in wastage elimination by adequate plant control.

The reuse of relatively clean wash waters may be practiced. Strong processing liquors can be recovered or used in other places in the mill. In one instance, caustic boil-out liquors were diluted and reused to kier cotton cloth with excellent results. Savings in chemicals and reduction in waste resulted. Prior to the reuse of this strong waste, the municipal treatment plant required an additional 20,000 pounds of sulfuric acid per month for pH adjustment.

The reuse of sulfur black dye liquors is customary in the hosiery industry. The dye vat contents is retained, made up to strength and reused. This type of economy should be extended to other dyes and other processes.

Continuous processes produce minimum amounts of waste and should be extended to include all possible processes. Likewise, the judicial use of counterflow principles will greatly diminish the liquid wastes.

Recovery Practices

Recovery holds promise for those liquors of high chemical strength such as the caustic mercerizing liquors, caustic boil-off wastes and kier liquors. Mercerizing liquors are usually reused or recovered by dialysis or evaporation. Evaporation is not feasible for kier liquors but dialysis shows promise.

Precipitation of the dye from waste liquor has been tried on an experimental scale. The wasted dye (approximately 10 percent of the original amount) is highly dispersed, requiring efficient precipitation for satisfactory recovery. Both dye and precipitating agents have been recovered. This process is complicated by the necessity of separating the various wastes within the mill.

Independent Waste Treatment Plants

Chemical precipitation is the most common method of textile waste treatment. This method lends itself to the enormous variations encountered and is the only method by which concentrated wastes can be treated successfully. Adjustment of pH may be considered chemical treatment, especially when a precipitate is formed upon neutralization. Large chemical dosages are required to overcome the dispersing agents employed during the application of dyestuffs.

The disadvantages of chemical treatment lie in the sludge disposal problem and cost of treatment. Concentrated wastes require large amounts of coagulants and produce enormous volumes of sludge. The sludge appears to be amenable to drying on sand beds. Cost may be reduced by recovery of the chemicals. A Dutch plant precipitating textile wastes in conjunction with domestic sewage recovers alum, the coagulant, by treating sludge with sulfuric acid. 80% of the alum is recovered.

The most common chemicals used in chemical treatment of cotton textile wastes are:

Ferrous and ferric sulfates
Aluminum sulfate
Ferric chloride
Sulfuric acid
Calcium hydroxide (lime)
Calcium chloride

Lime has been used to precipitate color shop wastes, while copperas and lime or calcium chloride is best for indigo. In general, copperas and lime are the most universally successful reagents for textile wastes besides being the most economical. Acids or alum should never be used for precipitating sulfur dyes because of the evolution of hydrogen sulfide.

Treatment with Municipal Sewage

Textile wastes discharged to municipal sewers are usually treated by the municipal sewage treatment plant. Holding tank capacity for 24-hour compositing is virtually a necessity. Poisonous substances should be removed from the waste when subsequent treatment processes involve biological action. It is advisable to have arrangements whereby the mill superintendent notifies the sewage plant operator whenever strong batches of wastes are discharged. Large volumes of textile wastes may require pH adjustment or pretreatment, especially when biological purification processes are used. Proper provision should be made in design of sewers and the sewage treatment plants to handle the waste volume and additional pollution load.

Activated Sludge Process - The activated sludge process has been used to treat combinations of sewage and textile wastes. This method provides the best color removal when successfully operated. The volume of sewage must be large and the waste discharge controlled. Pretreatment is oftentimes required by many municipalities. One mill neutralized sulfur dye wastes and aerated to remove hydrogen sulfide prior to discharge into the municipal sewer. Pretreatment with ferric chloride has been used to aid color removal and prevent sludge bulking. One plant requires proportioning of textile waste to sewage flow, pH adjustment, chemical precipitation with alum followed by primary flocculation, reaeration, and then treatment by activated sludge. Results are excellent except when sudden doses of strong wastes appear. Large quantities of suspended solids in the aeration tanks aid color removal. Three percent sulfur dye wastes mixed with sewage have been successfully treated on an experimental basis. At present, one plant successfully purifies a 16 percent textile waste-sewage mixture and expects over 25 percent textile waste from cotton mills in the near future.

Biological Filters - Trickling filters withstand sudden shocks of pH variations and large loadings although color removal may not be satisfactory. Ninety percent purification has been obtained which is similar to treated domestic wastes. Recirculating filters have been used experimentally to treat mixtures of sewage and textile wastes. Strong mixtures can be successfully treated, especially when the pH range of 6 to 8 is maintained.

Combinations - The most logical method lies between the two previously discussed processes, chemical and biological. The removal of the major portion of the pollutional load is best accomplished by chemical means followed by biological treatment for the residual. In this manner, the shock of the strong waste is absorbed by the chemicals while the pollutional qualities (B.O.D.) and residual tenacious color is removed by biological action.

Miscellaneous Corrective Measures

Textile wastes are usually hot. Heat exchangers may be installed, recovering heat and lowering waste temperatures. This type of recovery has been overlooked in the textile industry. Storage of the wastes with subsequent mutual reaction and neutralization, possibly with precipitation, reduces pollution. Screening may prevent fiber loss and remove large floating objects. Screens are necessary when pumps are required.

Kier liquor has been successfully digested, producing large amounts of gas. It has been proposed to pipe waste kier liquor direct to the digestion tank of the municipal disposal plant. Allowing for the difficulties of piping the waste, this solution appears practical.

Toxic wastes should be eliminated by separate treatment or lagooning. The cheapest method is to lagoon the waste allowing it to evaporate and seep into the ground.

Concentrated wastes such as slasher waste and color shop (print waste) starch may best be incinerated.

Effluent Disposal

Standards for the discharge of textile wastes have been suggested. These standards are based upon suspended solids, B.O.D., total solids, alkalinity and acidity, color, and absence of toxic materials. The treated textile waste should compare favorably in respect to suspended solids, B.O.D., and total solids with the effluent from the required domestic sewage treatment unit. A color of 100 or less (platinum-cobalt) has been taken as satisfactory for a plant effluent although this is a rigid standard and imposes hardship upon the disposal plant. The pH should range between 6 and 8, and toxic material should be absent. Solids standards have not been proposed in the United States although they have been suggested in England.

Bibliography

(1) Read, William Thornton, Industrial Chemistry, John Wiley and Sons, New York (1933).

(2) Rogers, Allen, Manual of Industrial Chemistry, D. Van Nostrard Co., Inc., New York (1931).

(3) Dyer, E. Textile Fabrics, Houston Mifflin Co., (1927).

(4) Geyer, John C. and Perry, William A.; Textile Waste Treatment and Recovery, The Textile Foundation, Inc. Washington, D. C. (1936).

(5) Texas State Department of Health, Textile Mill Wastes Treatment Study.

(6) Porges, Ralph, Horton, Robert K. and Baity, Herman G.; Chemical Precipitation of Textile Wastes and Studies of pH Control. Sewage Works Journal Vol. XI (1939).

(7) Baity, Herman G.; Textile Waste Treatment. American Diestuff Reporter (October 3, 1938).

(8) Miles, Henry J. and Porges, Ralph; Textile Waste Studies in North Carolina. American Dyestuff Reporter (Dec. 12, 1938).

(9) T.V.A. and U.S.P.H.S. Special Study of Industrial Wastes from a Hosiery Mill. Unpublished Report. (1939).

(10) T.V.A. and U.S.P.H.S. Special Study of Industrial Wastes from Knit Products. Unpublished Report (1939).

(11) Mathews, J. M.; Application of Dyestuffs, John Wilen and Sons, New York (1920).

(12) Campbell, Maxwelton S.; The Disposal and Recovery of Textile Waste Liquors. Chemical Precipitation of the Color Shop Wastes. Textile Research (1935).

(13) Stern, Boris; Mechanical Changes in the Cotton Textile Industry. Monthly Labor Review (Oct. 1937).

(14) Trice, M.F.; Hosiery Mill Wastes as Related to Stream Pollution and Sewage Treatment. N. C. State Board of Health. (1931).

(15) Hoover, C.R.; Treatment of Liquid Wastes from the Textile Industry. Industrial and Engineering Chemistry. (Nov. 1939).

(16) Henderlite, J.H. Jr.; Experiments with Ferric Chloride in Removing Color from Textile Dye Waste at Gastonia, N.C. Journal N.C. Sewage Works Association (1933).

(17) Miles, Henry J. and Porges, Ralph; Treatment of Sulfur Dye Waste by the Activated Sludge Process. Sewage Works Journal (March, 1938).

(18) Miles, Henry J. and Porges, Ralph; Treatment of Sulfur Dye Waste by the Activated Sludge Process, II Further Studies of Optimum Operating Conditions. Sewage Works Journal (Sept. 1938).

(19) Porges, Ralph and Miles, Henry J.; Treatment of Sulfur Dye Waste by the Activated Sludge Process. III Dewatering of a Sulfur Dye-Sewage Mixture. Sewage Works Journal (Nov. 1939).

(20) Chrisco, H.F., White, A.M. and Baity, H.G.; The Effect of Precipitants on Textile Waste Liquors. Sewage Works Journal (July 1933).

(21) Champbell, M.S.; The Disposal and Recovery of Textile Wastes, Part I - Disposal by Chemical Precipitation by Biological Treatment, by Superchlorination, etc. Textile Research, (1935).

(22) Porges, R., Miles, H.J. and Baity, H.G.; Some Effects of Sulfur Dye Waste Upon Sludge Digestion. Sewage Works Journal (May 1940).

(23) Rudolfs, W. and Setter, L.R.; Industrial Waste in New Jersey. N.J. Agr. Exp. Station Bulletin 610 (Nov. 1936).

(24) Weston, Robert S.; The Treatment of Textile Wastes. Sewage Works Journal (July 1939).

(25) Mengel, C. W.; Observations of Textile Waste Treatment. Civil Engineering (May 1940).

(26) Rudolfs and Kessener; Some New Developments in Sewage Treatment in Holland. Water Works and Sewerage (May 1939).

(27) Porges, Horton, and Baity; Studies on the Treatment of Sewage and Textile Wastes by Recirculating Filtration. II Sulfur Dyes Waste on Batch Basis. Unpublished Report.

(28) Porges, Horton, and Baity; Studies on the Treatment of Sewage and Textile Wastes by Recirculating Filtration. III Kier Liquor or Batch Basis.

(29) True, A.C.; Disposal of Waste from Dyehouses and Textile Operations, Journal of the Am. W. W. Asso. (July 1924).

(30) Porges, Horton, and Gotaas; Chemical Precipitation of Sulfur Dye Wastes on a Pilot Plant Basis. Unpublished Report.

(31) Porges, Horton, and Gotaas; Kier Liquor Waste. Precipitation on a Pilot Plant Scale. Unpublished Report.

(32) Streeter, H.W.; The Sanitary Classification of Stream Waters in Connection with Pollution Abatement Programs. Activities Bulletin Ohio River Pollution Survey (March-April 1940).

(33) Textile Wastes as Related to Stream Pollution and Sewage Treatment. N. C. State Board of Health. Unpublished Report.

(34) Worth and Baity; Durham Report, Unpublished (1928).

(35) Nichols, C. M.; Discussion on Chemical Precipitation of Textile Wastes. Sewage Works Journal (Sept. 1939).

(36) Modern Sewage Disposal, Anniversary Book of the Federation of Sewage Works Journal (1938).

(37) Siebert, Christian L.; A Digest of Industrial Waste Treatment. Pennsylvania Dept. of Health (April 1940).

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

I-11
Rev.8-39

(Not an Actual Plant)

TEXTILE WASTES

Plant Southern Cotton State Alabama Ref.No. Te-260

City Ford City County Cobert Main Watershed Tennessee

Address 1000 Shore Drive Sub-watershed Cedar Cr. (1/2 mi.)

Informant Mr. W. Blank Title Super. Principal Product Cotton

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	80	250	275
Maximum	144	300	310

Seasonal variation Peak during Spring and Summer

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	Municipal	32,000	40,000	None
Industrial	River	295,000	400,000	"
Cooling	Private Pond	No est.		"

RAW MATERIAL: Lbs. per Yr. Cotton 19,000 lbs./day - Yarn 800 lbs./day

Wool: Grease Scoured Substitutes

Rayon Silk

Chemicals:- Soap Oils

Dye stuffs Bleach Chlorine

NaCl, Na_2SO_4, H_2SO_4, NaOH, Acetic Acid

PROCESS:- Scoured 18,000 lbs./day Dyed 9500 lbs./day

Bleached 18,000 lbs./day - Print Goods 5000 lbs./day

PRODUCTS:- Cotton Goods 19,000 lbs./day

WASTES:- Quantity 295,000 g.p.d. How estimated Meter Records

Character:- Washings Acid

Process Alkali

Possible spills

Segregation of Strong Wastes

Difficulties

Treatment Lagoon

Analyses:- Number None Date By whom

Appearance

OUTLET:- Where to Cedar Creek

Description:	Size and Shape	Material	Location	Elevation
1.	24" circ.	Tile	Rear of Plant	
2.				
3.				

Gaging possibilities Within mill, manhole in storeroom

Conditions below outlet: Color Noticeable

Turbidity High Deposits Sludge banks

SANITARY SEWAGE: Disposal Raw to Creek Persons tributary 290

REMARKS

Survey by John Jones Date 2-1-41

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI,OHIO

INDUSTRIAL WASTES

River Mileage Index No. T 260

Type of Plant Textile - Cotton State Alabama

Name of Plant Southern Cotton Company

Municipality Ford City Main Watershed Tennessee

County Colbert Subwatershed Cedar Creek (1/2 mile)

Address 1000 Shore Drive

Source of Information Mr. Will Blank, Superintendent

Plant Operation:-

Av. 80 hours per week, 250 days per year.
Max. 144 hours per week, 300 days per year.
Employees Av. Office 11, plant 275
Max. Office 14, plant 310

Seasonal Variation:-

Peak during spring and summer.

(Survey report continued on next page)

Survey by John Jones Date 2/1/41.

Sewered Population Equivalent Computation:-

Factors used - Computed from breakdown of Mill processes

B.O.D. Suspended solids

Sewered population equivalent* based on B.O.D. 3900

Sewered population equivalent* based on suspended solids

Remarks:

Factors in "Cotton Guide"

Computation by: John Doe Date 2/10/41. Cincinnati Office

Note: This computation is of a preliminary nature and may b
subject to revision as more information on this plant
or the factors used becomes available.
*(Rounded to nearest 100)

T 260

Southern Cotton Company,
Ford City, Ala.

Water Supply - Drinking - from city Av. 32,000 Max. 40,000
Industrial - River Av.295,000 Max.400,000

Raw Materials - Raw Cotton 19,000 lbs. per day
Yarn (Indigo dyed) 800 lbs. per day

Accessory chemicals typical of cotton processing mills. Volumes may be estimated from formulas.

Products -

5,000 lbs.	per day print goods.
9,000 lbs.	per day dyed material.
4,000 lbs.	per day bleach finished.
1,200 lbs.	per day Denim.
19,200 lbs.	per day Total output.

Wastes - Total Metered - 295,000 gals/day

Process	lbs. of goods	Gallons	P.E.
Slashing	9,000	300	12
Desizing	2,000	4,000	192
Kiering	18,000	38,000	1,764
Bleaching	12,000	75,000	180
Souring	12,000	30,000	150
Mercerizing	700	21,000	58
Direct Dyeing	5,000	18,000	460
Vat Dyeing	2,000	40,000	260
Sulfur Dyeing Raw	2,000	20,000	720
Developed Dyeing (Stock)	500	4,500	50
Print Works	5,000	25,000	75
Finish		200	20
Total		276,000	3,941

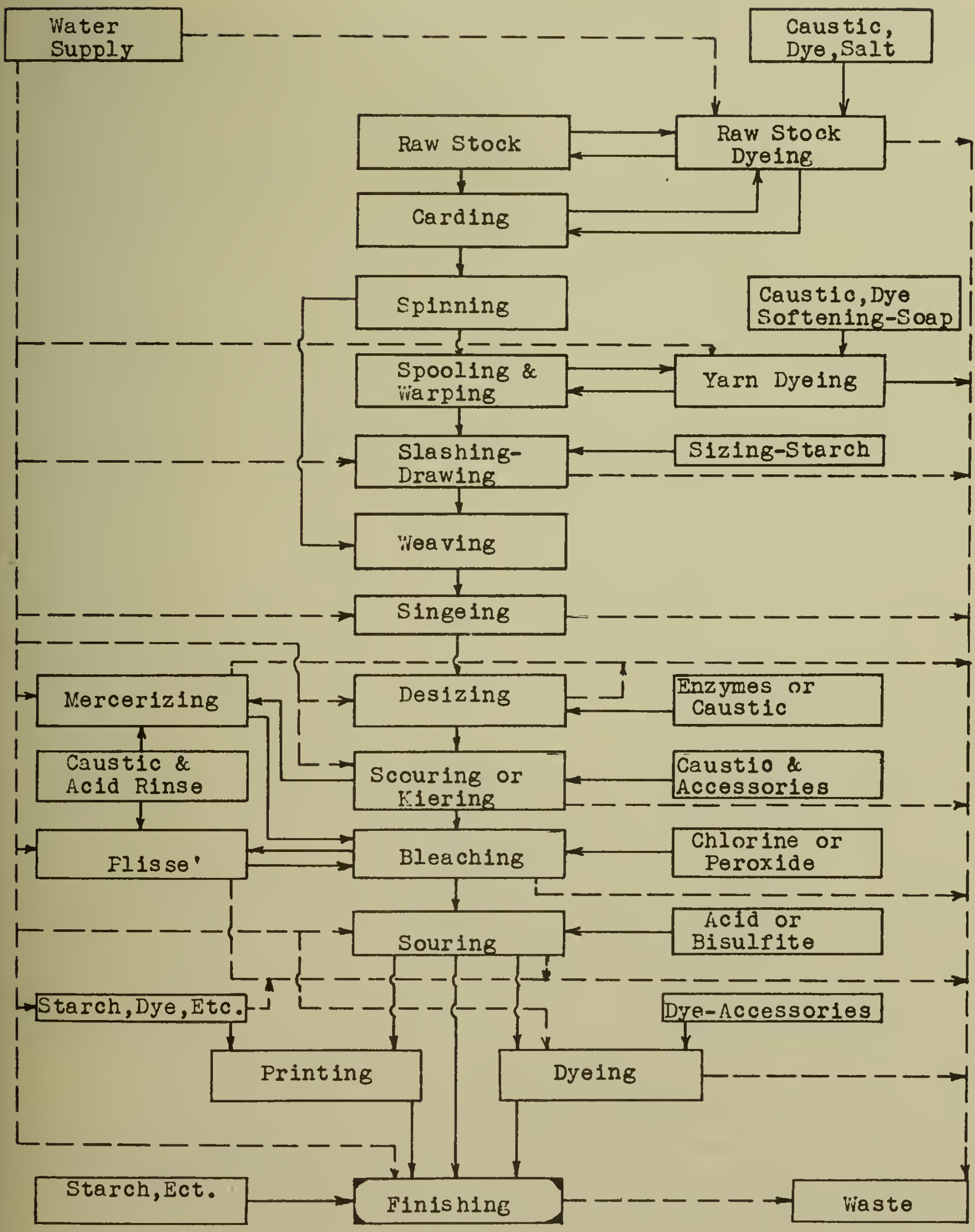
Outlets - 24" circular tile leaving the plant at the rear loading platform. This pipe carries the waste from the entire plant. Best possibility for sampling and gaging is within the mill. Manhole accessible in stockroom.

Process and Wastes (Field Notes)

Wastes	Form of Cotton	Pounds Per Day	Volume of Waste	Chemicals used Amounts	Type & Capacity Machine	Preliminary Treatment	After Treatment and Rinses
Slashing	Warp	12,000	300 g.	760# Starch	Continuous	(Batches discharged daily)	
Desizing	Cloth	2,000	4,000	-	Enzyme Steeping	Wet-out	2 Rinses
Kiering	"	18,000	38,000	540# NaOH 54# Na_3PO_4,54# Na_2SiO_3	Pressure kier-1 boil 3,000 g. - 9,000#	-	1 Rinse
Bleaching	"	12,000	96,000	250# Cl_2	Continuous	Rinse	Rinse
Souring	"	12,000	42,000	H_2SO_4	Continuous	-	Rinse
Mercerizing	"	2,500	75,000	Caustic (Conc) Acid Rinses	Caustic (Vat) Acid Rinse-Continuous	-	1 acid rinse 2 after rinses
Miscellaneous							
Dyeing	-	9,500	-	-	-		-
Direct	Cloth	5,000	18,000	1% dye, 30% salt	-	-	Rinse
Vats	"	2,000	40,000	5% dye,NaOH,Hydrosulfite	-	-	-
Sulfurs	"	2,000	20,000	10% dye,10% Na_2S,40% salt	Continuous	-	-
Developed	Raw Stock	500	4,500	10% dye,10% Na_2S,40% salt	Batch Process	-	-
Etc.Print Shop	Cloth	5,000	25,000	-	(No waste from Machine -	washing of	vats, buckets,etc.)
Finish	-	-	200	Starch	Continuous	(Dumped in Batches)	
Periodic							
Spills							

FLOW DIAGRAM

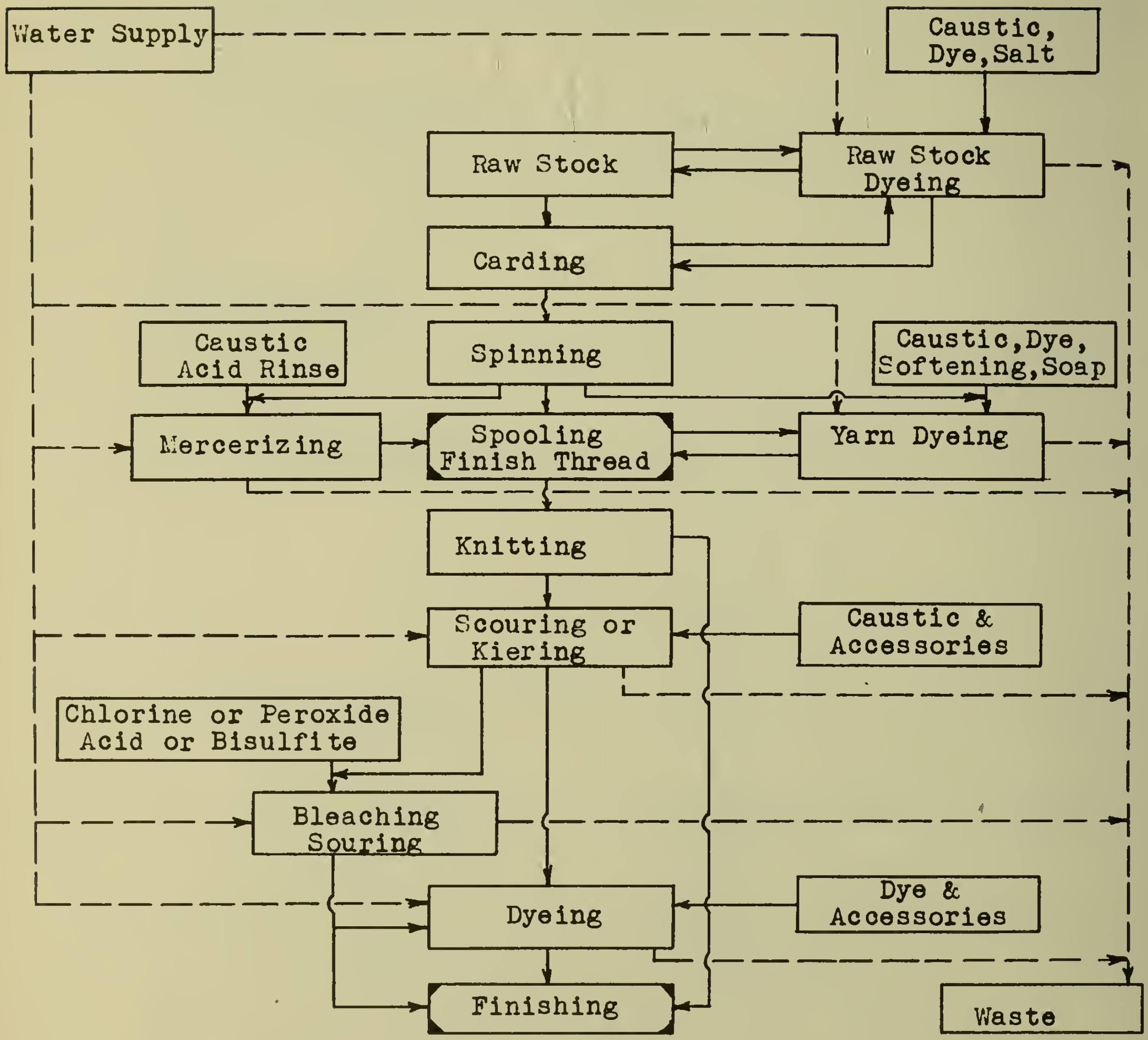
COTTON PIECE GOODS



Ohio River Pollution Survey
U. S. Public Health Service
1942

FLOW DIAGRAM

COTTON THREAD AND KNIT GOODS



Ohio River Pollution Survey
U. S. Public Health Service
1942

OHIO RIVER POLLUTION SURVEY

DISTILLERY

An Industrial Waste Guide to the Distillery Industry

APPENDIX "VI" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

	Page
Abstract	D-1
Description of Process	D-2
Raw Materials and Products	D-8
Sources and Quantity of Waste	D-12
Character of Wastes	D-14
Pollution Effects	D-17
Remedial Practices	D-17
Bibliography	D-20
Note Taking Form	D-21
Inspection Report	D-22
Flow Diagram	D-24

List of Tables

D-1	Strength in Parts per Million and Sewered Population Equivalents of Various Distillery Wastes per Thousand Bushels of Grain Mashed Daily or per Five Thousand Gallons of (100) Proof Spirits Produced Daily	D-1
D-2	Theoretical and Practical Yield at Distilleries	D-10
D-3	Typical Units per Bushel Mashed	D-10
D-4	Typical Units in Molasses or Cane Syrup Distillation	D-11
D-5	Average Analyses of Corn and Rye (Based on 114 Analyses of Corn and 57 Analyses of Rye) in Percent	D-14
D-6	Solid Matter of Corn and Rye in Distillers Slop in Percent of Original Grain	D-14
D-7	Analyses of Various Wastes	D-15
D-8	Analyses of Combined Wastes in Grain Distilleries	D-16
D-9	Population Equivalents of Various Wastes	D-16

Abstract

The production of alcohol by fermentation and distillation is accomplished with the use of corn, rye and malt for the production of whiskey; and molasses or cane syrup for the production of commercial or industrial rum and industrial alcohol.

Wastes developed in these processes are highly organic, acid, and contain a major portion of their solids in solution. Besides the carbon dioxide recoverable from fermentation, aldehyde and fusel oil are products of rectification.

Disposal of wastes is commonly by stock feeding, evaporation or discharge to the streams. Evaporation, in use at a number of large distilleries, recovers valuable spent solids from grain distillery waste, for use as stock feed, while potash and nitrogen are recovered from molasses or cane syrup distillery waste.

Various treatments of distillery wastes have been attempted. Chemical precipitation has met with but little success. Anaerobic digestion, followed by trickling filters, has shown promise on a pilot plant scale but is not in commercial use in the distillery industry.

Table D-1 gives the strengths of various wastes discharging from distilleries, as the most up-to-date data available. Grain distillery thin slop strength applies to distilleries using corn and returning one-third of the screened slop to the fermentor.

Table D-1 Strength in Parts per Million and Sewered Population Equivalents of Various Distillery Wastes per Thousand Bushels of Grain Mashed Daily or per Five Thousand Gallons of (100) Proof Spirits Produced Daily.

Waste	Analyses - p.p.m.		Sewered Population Equivalents *	
	B.O.D. (5-day,20°C)	Suspended Solids	B.O.D.	Sus.Solids
GRAIN DISTILLERY (Corn)				
Thin Slop	34,000	-	55,000	-
Tailings	740	-	50	-
Evaporator Condensate	1,200	-	1,500	-
Combined Wastes **	-	-	3,500	2,260
MOLASSES DISTILLERY				
Molasses Slop	33,000	3,270	60,000	5,000

* Based on 0.168 lbs. of B.O.D.(5-day 20°C) per capita.

** No intentionally discharged slop included.

Description of Process

The process of distilling raw spirits is much the same in all plants, although there may be considerable variation in the ingredients used. The description which follows, arranged as nearly as possible in sequence, covers the practices in a bourbon ortypical Kentucky distillery with occasional comments as to comparison with similar processes.

Milling

The production of distilled spirits usually is accomplisned from grain, either rye or corn, separately or in combination. As a preliminary step, dust, stones, chaff, husks and foreign matter are removed from the grain by the use of screens or pneumatic machines. The refuse may be retained in bags for sale to farmers or feed merchants, or discharged into a vessel of water for final disposal to the sewer. The grain is then ground to a size desired by the individual distiller. After milling, it is stored temporarily in bins or scale hoppers. Storage facilities are usually maintained for grain as received and milling takes place the day the grains are to be used.

"Mashing", Cooking and Cooling

From the scale hoppers or bins the grain is discharged into the mash tub or cooker. In many plants, particularly the smaller ones, the open mash tub is used. It is equipped with steam coils or direct steam jets for heating purposes, cooling coils, stirring mechanism, and water facilities. The vacuum type cooker, generally used at the larger plants, is a covered dome-shaped vessel with direct and indirect steam for heating, cooling coils, water, vacuum and pressure facilities. An opening in the dome permits addition of the mashing ingredients.

The quantity of water added to the milled grains depends upon whether direct or indirect steam is used in heating and usually is from 20 to 24 gallons per bushel of grain mashed. The length of time and temperature required in mashing is dependent upon the grains used. If corn is the predominating ingredient instead of rye, the temperature must necessarily be higher with the time longer, in order to reduce the grains to the pasty form required for saccharification. This temperature variation ranges between 158°F. to 200°F. When thorough digestion is complete, the temperature is reduced to approximately

120°F. and the malt is added. The diastase, an enzyme of the malt, attacks the ruptured starch cells and converts them into dextrose and maltose sugars. The quantity of malt varies between 10 and 15 percent of the total batch. Vacuum cookers permit cooling under vacuum and digestion under pressure.

After the malt has been added and the saccharification is complete, the batch is cooled down to about 80°F. in the cooker or, if the cooker is needed for the following batch, this final cooling is accomplished in a drop tub. The stirring necessary in all cookers and tubs to keep the mash from lumping is usually carried out by the use of mechanically operated paddles.

Yeasting

Yeasting, or the addition of yeast to the mash, is carried on with the utmost care and supervision. The success of this important step depends largely upon the sterilization of the utensils and machinery through which it is accomplished. Many distillers have attributed their success in producing a particular brand of whiskey to the activities carried out in the yeasting room, often in the utmost secrecy. In general, a pure culture yeast is used to propagate a culture that is particularly suited to the type of fermentation practiced, be it of a sour or sweet mash consistency.

The yeast mash or starter mash is a batch of small grains, as malt and rye, prepared and saccharified as in the large cookers previously explained, but with more care in processing. After the final cooling to approximately 120°F., it is inoculated with a lactic acid bacteria and allowed to work over a period of 24 to 36 hours. When the proper degree of acidity has been reached, part of the batch is removed to be used as a starter for the succeeding batch. The pure culture yeast is now added to the batch in sufficient amount for inoculation and, after several hours' working, the batch is added to the fermenters. The quantity of yeast mash may vary but generally about 1 to 2 pounds of rye and a like amount of malt are used per bushel of grain in the mash.

Malting

The preparation of malt in this country is accomplished by regular malting companies, actually far removed from the distilleries, and located near or in the grain belt.

Any grain can be used for preparing malt but generally barley is the most suitable. The process consists of grinding the grain to the desired fineness and, by the addition of moisture, developing the germ to the highest degree of activity to convert starch to sugar. The resulting meal is dried and bagged for shipping. The economical quantity of malt necessary depends upon its diastatic power, soluble starch available, and ability toward liquefaction.

Fermentation and Back Slopping

Fermentation is generally accomplished in large, wooden, straight-sided, open tubs, located in a building with heating facilities. Some plants are equipped with stainless steel or glazed tile fermentors although the latter has not proven successful as the lactic acid produced in fermentation attacks the cement joints between the tiles making repairs frequently necessary. The covered fermentor is now being used in many plants for the recovery of carbon dioxide gas given off in fermentation, to manufacture liquid and solid (dry ice) carbon dioxide, and to prevent the loss of 1 to 2 percent of alcohol by evaporation.

The fermentation is carried on at room temperature averaging about 70°F. for periods of either 72 or 96 hours. The mash starts at a temperature of about 72°F. and approaches 86° to 90°F., when maximum activity is reached.

The cooker mash is pumped to the fermentors from the drop tub through the cooling coils or cooling tank and the yeasting mash is added by gravity to the same vessel. In order to increase the activity of fermentation, it is necessary to dilute the saccharified mass with sterile water or slop which has been through the process of distillation and therefore is available in a sterile condition. Usually sterile slop is screened, cooled to the fermentation-starting temperature, and used. This slop, containing lactic acid and considerable dissolved solids, affords essential bacterial food for fermentation. The procedure is known as "back slopping" or"setting back," and the quantity used averages about 1/3 of the total fermenting batch. However, if the slop, when dealcoholized, is to have solids recovery possibilities, it is of utmost importance that the density of the fermenting wort be kept high by reducing the amount of "slop back." The fermentors usually carry a volume of about 45 gallons per bushel of grain used, including a 1/3 slop return. This may be varied in accordance with the practices of the distiller.

After fermentation is complete, a rich amber colored liquor remains containing 5 to 8 percent alcohol, fusel oil, aldehyde, water, acids and solid matter. This liquor, generally spoken of as beer, is now run to the beer well where agitation is available and where it can be pumped at a uniform rate to the distilling equipment.

Distillation

The distillation is accomplished in one of two types of distilling apparatuses known as the continuous multiple type and the three chamber or batch type. Many prefer the latter as it is claimed that a richer, heavier bodied product is produced. The multiple type is more economically operated, requiring less steam and attention.

The continuous still is a high, small diameter column fitted with many perforated plates, equipped with down pipes alternating between plates from one side to the other so that as the mash enters about one fourth of the way down from the top and starts on its downward course a zigzag path is maintained. Before entering the still, the beer passes through a beer heater which raises the temperature to a point, where, upon entering the first still plate, an economical evaporation will become effective. The live steam is administered through the bottom and passes up the perforations in the plates, thus heating the beer anddriving off the alcohol. The vapors escaping from the still are directed to the heat exchangers in connection with the beer heater. Some vapors, on condensing, are refluxed to the topmost section of the still for re-evaporation. The remaining vapors pass on through the condensers and emerge in liquid form, known as low wines at approximately 105 proof strength. The remaining mash, known as slop, continues to the bottom of the still and escapes to the disposal plant.

The three chambered or rye whiskey still, as it is sometimes called, consists of a column similar to but shorter than the continuous still. It has three reservoirs, one above the other, where batches of the beer can be "boiled off" in stages of 15 to 20 minutes for each chamber, starting with the top and continuing until the bottom chamber is reached. The vapors are directed to a condenser and the liquid collected in the low wine tank. Slop is released for disposal at the bottom of the column.

In both type stills the operation is continued until the fermented beer has been passed through the distilling apparatus. The final beer going through the distilling apparatus, after a day's run, has a low density due to the dilution with water in washing down the fermentors, beer well and distilling apparatus. The quantity of this water will average between 50 and 100 gallons per fermentor and similar amounts for the beer well. The apparatus wash will possibly add 200 to 300 gallons additional.

Rectifying

The vapors coming from the main still, when condensed, contain alcohol, water, aldehyde, fusel oil and other impurities. These impurities, which are objectionable, must be separated from the alcohol by further processing. This is accomplished by distillation at lower temperatures, and at some plants is the source of aldehyde and fusel oil by-products. At the majority of distilleries, however, this distillation is carried on only so far as to free the alcohol from the largest percentage of the products. In these plants the doubler is generally used either by the continuous process or the batch method. The doubler is a closed kettle equipped with heating coils, vacuum outlets, an inlet lines. In the continuous process the vapors partially condensed are freed at the bottom of the kettle and allowed to pass into a body of liquid held at the bottom of the doubler. This liquid is maintained at a temperature capable of volatiliz the alcohol under vacuum. The vapor is directed to dondensers, which are water cooled, and emerges as liquid known as high wines at approximately 110 proof. The batch doubler, which is similar to the continuous type, collects all the low wines from the day's run or until the capacity is reached before beginning the distillation.

Many variations in rectifying are practiced. Some distill prefer using an additional rectifying column on the main still for the second distillation, others using the doubler type, reroute a percentage of the low wines through the main still wi the balance going its usual course.

Where increased proof is desired and by-products such as aldehyde and fusel oils produced, a heating vessel such as the doubler is used in conjunction with a rectifying column, dephlegmators and condenser especially designed to separate the various volatile "heads." This produces a spirit alcohol of 190 proof, which may be used industrially or for cutting and blending whiskies.

In rectifying with the doubler by either the continuous or batch methods, water and impurities are left behind in the form of a colorless liquid known as lutter water or "tailings."

This is often discharged to the sewer after a day's run but in some plants is run through the main still the following day ahead of the fermented mash, and passes out through the slop discharge. The quantity produced varies with the efficiency of the distilling apparatus, density of slop, and with the care in operation. An average figure will approach three-quarters to one gallon per bushel of grain mashed.

Cutting, Aging, Blending and Bottling

The high wines coming from the final condensers may be reduced in proof according to the desires of the distiller. This may be accomplished by adding distilled water, and is known as "cutting."

In order to produce a mellow palatable beverage, suitable to the demands of the consumer, an aging process is carried out by using oak barrels which may or may not be charred on the inside. Usually the charred type is selected and the aging process carried on from two to eight years. As the barrels are filled they are stored in warehouses, with the proper ventilation and under controlled temperature. In the aging process the alcohol gives up its impurities to the walls of the barrel and in turn absorbs the color known as whiskey brown, thus causing a shrinkage of the volume of whiskey and an increase in the proof strength.

The bottling department is generally located in a building removed from the main distilling operations. The operations of cleaning, filling, capping and labeling are usually automatic although some plants resort to hand operations on part or all of these functions. Bottles consisting of quarts, fifths (of a gallon), pints and half-pints are the usual sizes. The cleaning machine either is a water spray or air blower type from which the bottles go to the filler, capper, labeler, etc.

In preparing the whiskey for bottling, the barrels are emptied into a tank through a filter where the whiskey is tested for proof and increased or decreased as desired, distilled water being used for cutting or reducing, and 190 proof spirits added for increasing the strength. Blending, carried on at this time, consists of mixing various aged whiskies to produce a flavor particularly bodied to suit the demands of the consuming public.

Government Regulations

In the distilling industry, where alcohol spirits are produced, government regulation has been found necessary and successful to reduce the loss due to theft and leakage, in order to accurately tax the amount of distillation. For this reason, every distillery has one or more government employees who must check the amount of raw material used against the alcohol yield, check the amount going to and from storage, amount bottled and make various other necessary records. All vessels used in processing, beginning with grain hoppers, cookers, kettles, tubs, stills, fermentors, etc., must be plainly marked as to capacity; valves, couplings, joints, etc., must be securely sealed, beginning with the main still and ending on the final condenser; buildings containing whiskey or alcohol securely locked and fastened; painting of pipes, water, steam, distilled water, slop, etc., various colors so that they can be followed easily; and many other necessary steps in order to account for the maximum possible distillation.

Rum Distillation

Although this guide has been particularly prepared with reference to the manufacture of rye, corn or bourbon whiskies, it is applicable, in part, to the production of industrial rum or commercial alcohol from black strap molasses and beverage rum from sugar cane. As no grain is used in this processing, the steps preceding the fermentation are much simpler and quicker, sulphuric acid being used to invert sucrose to glucose and levulose by chemical action. The quantity of sulphuric acid used averages 5 gallons per 1000 gallons of molasses. By-products of dealcoholiz molasses wastes in recovery plants consist of potash and nitrogen. Molasses before fermentation is generally diluted in ratios of 1 to 5 or 1 to 3, depending upon whether recovery practices are to be carried out after distillation.

Raw Materials and Products

Water Supply

Water supply is an important item in the manufacture of alcohol or beverage spirits. The bulk of the water used is for cooling purposes and the best source of this supply is from springs or wells that have a low temperature. This requirement, however, has been somewhat changed in recent years, due to the use of refrigeration. In this case surface supplies have been found satisfactory.

Although process water consumes a small portion of the supply, it is desirable that this water be from springs or deep wells that are high in sulphates. This characteristic increases saccharification and fermentation, and thus, it is claimed, produces a beverage of better flavor.

The uses of water in a distillery may be varied, but the general major functions include cooling and condensing, processing, and washing floors and equipment. Minor uses consist of grain cleaning wash, bottle cleaning, distilling water, power house supply and sanitary requirements.

Cooling and condensing water varies between 300 and 600 gallons per bushel of mashed grain and approximately 180 gallons per gallon of syrup processed. These figures are general and may vary considerably at some plants where activities vary or equipment is inefficient.

Process water is used in preparing the mash and yeast for fermentation and usually is about 20 to 22 gallons per bushel in grain distilling. Molasses or cane syrup may be diluted to 1 to 3 or 1 to 5, depending upon the use of final slop, the maximum dilution being used where recovery of by-products is not practiced.

Washing water used on equipment and floors is dependent on the layout of plant and the desires of the operator. It may reach considerable proportions in some plants. Grain cleaning wash is the water used to absorb the dust and chaff cleaned from grain. Few plants use water for this purpose.

Grains

Raw materials consumed in the distilling industry consist chiefly of grains. Table D-2 lists these materials and also shows the theoretical and practical yield.

Table D-2 Theoretical and Practical Yield at Distilleries

	Pounds per Bushel	Fermentable Sugar and Starch		Yield in Proof Gallons* per Bushel	
		Percent	Pounds per Bu.	Theoretical**	Practical
Barley	48	65.5	31.4	5.41	4.50
Malt	34	60.6	20.6	3.55	3.00
Wheat	60	64.8	38.9	6.71	5.90
Maize (Indian Corn)	56	66.0	36.9	6.36	5.00
Rye	56	59.3	33.2	5.72	4.75

* A 100 proof gallon is a gallon of "that alcoholic liquor which contains one half its volume of alcohol of a specific gravity of 0.7939 at 60°F." 100 parts of 100 proof spirits contain 50 parts of alcohol and 53.71 parts of water by volum or 42.49 percent of absolute alcohol by weight. 100 proof spirit has a specific gravity of 0.93426 at 60°F. referred to water at 60°F.

** "The theoretical amount of starch required to produce a proof gallon is 5.8 pounds."

The quantities of raw material and products in a typical grai distillery are summed up in Table D-3.

Table D-3 Typical Units per Bushel Mashed

Unit	Total	Dry Weight
Corn and/or Rye Grain	0.9 bu. or 50.4 lbs.	- 44.8
Malt	5.6	5.0
Proof Gallons	5.0 gal.	
Back Slop (thin)	14 to 17 "	
Water (Process)	20 to 24 "	
Water (Cooling)*	30 to 600 "	
Total Spent Slop	42 to 51 "	
Total Slop for Disposal	28 to 34 "	
Total Thin Slop for "	25 to 27 "	

* Cooling towers may be used where supply is limited. In this case make-up water will average approximately 30 gals. per bushel.

Molasses or Cane Syrup

The amount of raw material and products in a rum or commercial alcohol distillery per gallon of raw material and per 5 gallons of 100 proof spirits, comparable to Table D-3 is shown in Table D-4.

Table D-4 Typical Units in Molasses or Cane Syrup Distillation

Unit	GALLONS	
	Per Gallon of Raw Material	Per 5 Gallons 100 Proof Spirits
Molasses or Cane Syrup	1.0	6.7
Proof Gallons	0.75	5.0
Water (Process)		
Recovery of Spent Slop By-Products Practiced	3.0	20.0
Non-recovery of Spent Slop By-Products	6.0	40.0
Back Slop	1.2 to 2.4	8 to 16
Total Spent Slop		
Recovery of Spent Slop By-Products Practiced	3.25	21.8
Non-recovery of Spent Slop By-Products	6.25	41.9
Water (Cooling)*	180.0	1200.0

* Cooling towers used where supply is limited.

Seasonal Variations

Many distilleries operate only during the winter months. Cold water is readily available in winter for cooling purposes and warehouse stocks can usually be replenished with part-time operation. Pollution problems are also less acute. Six months' operation is quite common. Other distilleries operate on a 12-month basis but at reduced capacity.

Employees

The number of employees required is subject to considerable variation. From 20 to 60 employees per 1000 bushels capacity are typical.

Sources and Quantity of Waste

Milling

In milling the grain and preparing it for mashing, some distilleries use screens and pneumatic machines to exclude the dust, chaff, stones, sticks, etc., from the finished meal. In order to dispose of this foreign matter and thus keep the dust from spreading through the mill, this is often discharged to a tank of water and is water-carried to the sewer. Another way of disposal is to collect it dry in bags and use it for poultry feed. It is apparent that the quantity of this material will depend on the cleanliness of the grain.

Yeast Room

Cleanliness in the yeast room is important and demands special attention. Here the yeast is prepared and cultures developed. During the process of yeasting, some small grains may find their way to the sewer in small amounts. As many tubs are required, washing and sterilizing of equipment produces a large waste discharge carrying yeast, grain and mash, and having a high oxygen consuming effluent. Waste flow may be from 5 to 8 gallons per bushel of total grain mashed.

Equipment Washes

Equipment washes include all processing and sterilization beginning with mashing and ending with fermentation, including cookers, mash tubs, drop tubs, fermentors, flake stands, beer well and distilling apparatus. After each run, or as equipment is through functioning for the day, it is given a final scrubbing with steam and water to clean out solids remaining after the washdown. This extra wash and sterilization carries to the sewer portions of mashed grain and fermented beer. A fair estimate will approach 500 gallons daily at plants up to 1000 bushels capacity with double this amount or 1000 gallons on plants above 1000 bushels and not exceeding 3500 bushels.

Tailings or Lutter Water

The tailings or lutter water, which includes the aldehyde and fusel oil retained in the doubler that is used in most plants, is quite often discharged to the sewer although some plants rerun it through the main still. In this case it finds its way to the slop discharge. It is low in solids and oxygen demand. The quantity produced will depend upon the condition of the fermented beer, operation and efficiency of the main still, refluxing appurtenances and finally the doubler itself. The estimated quantity of this waste is between 3/4 and 1 gallon per bushel of grain mashed.

Slop Effluents

The dealcoholized slop as it comes from the still is high in solid matter, approximately 50 percent of which is in solution. This effluent, averaging 42 to 51 gallons per bushel mashed, is passed over a double 0 punched hole screen, through which passes sufficient thin slop to make up the required quantity for "setting back" to the fermentors. The balance of the waste or whole slop of 28 to 34 gallons per bushel is either discharged, sold to farmers, fed to cattle, treated for recovery of solids, or used for irrigation.

If recovery is practiced, the slop is run over more double 0 screens until the moisture content is such that the screenings will not flow. From here the screenings go to a drag box, which is a mechanically operated machine, using an inclined screen, that reduces the moisture content to approximately 90 percent. Screenings then pass to a continuous press where a revolving belt aids in further reducing the moisture content. The press cake, as it is now called, continues on to a revolving steam drier, which delivers the spent grains at a moisture content usually around 5 to 7 percent, although this may be varied as required. The spent grains recovered, average from 8 to 10 pounds per bushel of total grain mashed. They are valued as a stock food, being used mostly as blending material.

The thin stillage collected from the screens, drag box and press are disposed of by any of the ways listed relative to the disposal of thick slop. This thin effluent represents approximately 26 to 28 gallons per bushel of grain mashed.

Spills

Even though satisfactory slop disposal practices may be followed at a distillery, there is often a slop loss to the sewer due to spills or careless handling, breakage of equipment and damaged grain or yeast cultures. Serious spillage may take place at the sales tanks where slop is dispensed to farmers. Small barrels or tanks, used to transport the slop, often run over and cleanup water may be strong. The amount of spill is normally low but may reach large proportions at times.

Character of Wastes

Solid Matter

The whole slop discharged from the still in the manufacture of grain alcohol and practicing back slopping has a solid content of approximately 6½ percent. Where screening and drying of spent grains are practiced, the removal of 2½ percent of grain leaves an approximate 4 percent of total solids for the thin slop.

Tables D-5 and D-6 are presented to show the constituents of the raw material and waste in a grain distillery.

Table D-5 Average Analyses of Corn and Rye (Based on 114 Analyses of Corn and 57 Analyses of Rye) in Percent.

Constituent	Corn	Rye
Water	10.0	8.7
Nitrogen Substance	10.5	11.3
Fat	5.2	1.9
Carbohydrates	70.7	74.5
Fiber	2.1	1.5
Ash	1.5	2.1
Total	100.0	100.0

Table D-6 Solid Matter of Corn and Rye in Distillers Slop in Percent of Original Grain

Constituent	Corn	Rye
Nitrogen Substance	10.5	11.3
Fat	5.2	1.9
Carbohydrates	15.7	29.5
Fiber	2.1	1.5
Ash	1.5	2.1
Total	35.0	46.3

The slop from molasses distilleries contains very little suspended matter and about 20 percent total solids. The tailings from the doubler or rectifying still, which is colorless and has a grain mash odor is very low in total solids. An actual analysis gave 200 p.p.m. 0.02 percent.

Acidity

Slop produced in the grain distillery are highly acid and cause serious damage to operation machinery and handling equipment. Screens in presses and drag boxes must be renewed from time to time because of its chemical action. The acidities average 12,000 to 15,000 p.p.m. and the pH value is about 3.8.

Population Equivalents

The population equivalent factors of wastes from distilleries, based on biochemical oxygen demand and suspended solids may be shown for undiluted effluents and for the total combined discharges, which will include all cooling and condensing waters.

Table D-7 gives a typical set of analyses on several waste effluents and Table D-8 gives typical analyses of combined wastes.

Table D-7 Analyses of Various Wastes

Determination*	Thin Slop (Grain)	Tailings	Evaporator Condensate	Slop (Molasses)
Acidity	11,900			
pH	3.7			
Total Solids	48,300	264		
Volatile Solids	45,300			
Suspended Solids				3,270
Chlorine Demand	541			
B.O.D. (5-day)	34,000	735	1,230	33,000

* Results in p.p.m. except pH.

Table D-8 Analyses of Combined Wastes in Grain Distilleries

Determination*	Plant A	Plant B	Plant C
Percentage of thin slop discharged	3%	37%	None intentionally
Alkalinity	278	452	186
Acidity	-	-	-
pH	7.2	7.3	7.5
Chlorides	27	25.0	4.0
Total Solids	742	1838	618
Volatile Solids	414	1200	356
Total Suspended Solids	360	1208	221
Volatile Suspended Solids	331	1081	166
Chlorine Demand	15.0	12.8	2.9
B.O.D., 5-day Total	250	2800	228

NOTE: Wastes at Plants A and B had been limed.
* All results in p.p.m. except pH and Slop discharged.

Average population equivalent based on biochemical oxygen demand and suspended solids is shown in Table D-9 for individual effluents and combined wastes.

Table D-9 Population Equivalents of Various Wastes

WASTE	Sewered Population Equivalent	
	Based on B.O.D.	Based on Susp.Solids
GRAIN DISTILLERY-per 1000 Bushels mashed daily or per 5000 gallons (Approximate) Proof Spirits		
Thin Grain Slop	55,000	-
Tailings	50	-
Evaporator Condensate	1,500	-
Combined Grain Distillery Wastes*	3,500	2,260
MOLASSES DISTILLERY-per 5000 gallons Proof Spirits		
Molasses Slop	60,000	5,000

* Does not include any intentionally released slop.

Pollution Effects

The chief effect of distillery waste pollution on streams is one of deoxygenation. Operation during the winter months, when temperatures are low and flows are high, tends to reduce complaints. Fish life near the sewer outfall is reported to flourish, being more plentiful than at other places in the stream. However, at lower points the suspended matter is deposited and at low flows the stream becomes septic and odors are offensive.

The effects of distillery wastes are pronounced in the vicinity of plants that are attempting to dispose of the slop by feeding to cattle corralled near or within several miles of the plant or by lagooning or irrigation to the land. In such cases the cattle waste or the slop washing to the stream may cause a serious pollution problem. However, the most serious objection and the common cause for complaint is fly breeding and obnoxious odors.

Remedial Practices

Screening and Drying

The process of screening and drying slop in a grain distillery involves trough screens, drag box, press and drier. Solids are reduced from 6½ percent in the whole slop to 4 percent in the thin or screened slop. The spent grains recovered have a value (1941) of approximately $22 per ton, and the practice of recovery of spent grains is found in practically all distilleries.

Cattle Feeding

The disposal of slop by cattle feeding at or near the plants has caused many complaints due to odors and due to effluents from pens discharging to streams. The practice has been to feed all slop produced to cattle, averaging one animal to every bushel of grain mashed. This has resulted in large herds numbering anywhere from 500 to 1,300 animals. Beside the slop, additional food is supplied in the nature of roughage and bean meal. This fattening of animals has produced an inferior class of meat rating a lower basic price. Because of market fluctuations, and the possibility of loss through fire and disease, the disposal method is not popular. Pen effluents, even though ponded for pumping to the land, often are washed to the stream, causing a pollution problem.

Farmer stock feeding has certain advantages and also disadvantages. The distilleries are required to erect tanks for dispensing the slop. The price of slop averages about five cents per barrel, although some plants make no charge. Necessary supervision of the dispensing station is an expense. However, the method is fairly successful at small plants, as costs to the distillery are low, the farmer is provided with stock food, and harmful effects on streams are reduced or eliminated, due to the large area of distribution. It is reported that with a balanced diet of 250 pounds of sweet clover to 100 gallons of slop, the production of milk is normal and the quality satisfactory.

Broad Irrigation and Lagooning

This method of disposal of grain distillery slop is used only to a limited extent today. It may be used during times of low demand for slop by farmers. The chief disadvantage is due to fly breeding and odor. Pumping is required, and frequent cultivation of irrigated land is necessary. Area of land irrigated approximates one acre for every 10,000 gallons per day of slop.

Evaporation

Evaporation of distillery slop affords a sanitary method of disposal and is used in numerous places, particularly at the larger distilleries where costs are reasonable. Costs for the smaller distilleries are excessive and as disposal to farmers is usually moderately successful at such plants, evaporation is seldom used. Several types of evaporators are on the market today, all of which employ multiple effects. The triple effect evaporator in use at distilleries has the advantage over the single effect in that about two and a half times the amount of liquid can be reduced with the same amount of heat. The process of evaporation requires a primary reduction of solids by screens, drag box and press, with the actual evaporation applied to the thin slop. The products of the evaporator are a thin syrup and a watery condensate. The thin syrup is thoroughly mixed with previously dried grains or with the press cake before entering the drier. The discharged concentrated grain is increased in protein content, with resultant increase in value from $22 to $30 per ton. The condensate from the evaporators containing some volatile solids and polluting properties, is discharged to the sewer. This waste discharge, an analysis of which is shown in Table D-6, can be used to advantage in the processing dilutions as it is in a sterile condition.

Anaerobic Fermentation

The treatment of distillery waste by anaerobic fermentation or digestion has been the subject of study by the Illinois State Water Survey and the process has been demonstrated on a pilot plant scale. The digested effluent was further treated at the pilot plant on a trickling filter after dilution in the ratio of 1 to 5 with trickling filter effluent. Due to the high nitrates in the filter effluent, this dilution practice was successful in overcoming objectionable odors. The trickling filter was operated at a rate of 250,000 gallons per acre, per day, based on the feed of digester effluent or 1,500,000 gallons per acre, per day, after dilution with trickling filter effluent. A stable effluent was obtained in which dissolved and nitrate oxygen exceeded the biochemical oxygen demand. The process is not in commercial use in the distillery industry.

Other Treatments

Other treatments noted in the literature involve many processes, some of which may have promising possibilities. A few will be described briefly.

A recent treatment plant at one of the larger distilleries makes use of a Dorr thickener to treat still slop, in conjunction with quadruple effect Swenson evaporators and Bird contrifuge machine. The thin slop from the thickener goes to the evaporators, and the settled solids to the centrifuge, with the thin waste returning eventually to the thickener. The cake from the centrifuge and syrup from evaporators are mixed and dried. Effluent from evaporators is said to be colorless with a slight grainy taste. Tests on this waste gave Methylene Orange Acidity of 17 p.p.m., Phenolphthalein Acidity of 172 p.p.m., pH 3.8, and B.O.D. 6.5 p.p.m. Analysis of final waste composite made at a later date gave Phenolphthalein Acidity 280 p.p.m., pH 3.6, B.O.D. 59 p.p.m., Settleable Solids 0, and Total Solids 60 p.p.m.

Reference is made to the treatment of filtrate, produced by heating slop to 240°F. and filtering through cloth. The filtrate may be further treated by a trickling filter or by chlorination and the lactate precipitated with the use of $CaCo_3$.

Bibliography

1. Municipal Sanitation Vol. 9, #2, Feb.'38 p.p. 134-142 "Maryland Continues Steady Progress in Industrial Waste Treatment."

2. Municipal sanitation Vol. 99, #5, May'38 p.p. 259-61 Complete Recovery of Distillery Wastes, C. S. Boroff & Dwight Miller.

3. State of Illinois, Water Survey Division Cir. #16, 1935 by A.M. Buswell, Ph.D. The Treatment of "Beer Slop" and Similar Wastes.

4. State of Illinois, Water Survey Division Bull.#32, Buswell & LeBosquet. Complete Treatment of Distillery Wastes.

5. U. S. Geological Survey, Water Supply & Irrigation Paper #179 - Prevention of Stream Pollution by Distillery Refuse.

6. Chemistry & Met. Vol.36 - Rectifying (Refluxes and Latent Heat).

7. Process Industries, Flow Sheets and Data Book by Reich.

8. Chemical & Metallurgical Engineering Vol. 36, 1929.

9. Manufacture of Whiskey, Brandy and Cordials, 2nd Ed. by Hirsch.

10. Thorpe's Dictionary of Applied Chemistry, Vol. 1.

11. Sewage Works Journal, Vol. 5, July 1933.

12. A Digest of Industrial Waste Treatment by Christian L. Siebert, Pennsylvania Department of Health, April 1940.

13. The Sharples Specialty Co., Britian 486,163, May 31,1938.

14. Private Communication.

15. U. S. Public Health Service Files.

DISTILLERY WASTES

(Not an Actual Plant)

Plant Old Bourbon, Inc. State Kentucky Ref.No. St-20.5

City High Rock County Moss Main Watershed Salt River

Address R.D., White Horse Pike Sub-watershed -

Informant F. W. Budd Title Distiller Principal Product Bourbon Whiskey

Plant Operation:	Hours per Week	Days per year	Plant Employees
Average	110	144	80
Maximum			

Seasonal variation Depends upon market conditions

WATER SUPPLY: -	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	City	100,000		None
Industrial				
Cooling	Wells	1,100,000		None

RAW MATERIALS:- Corn 2100 bu./day Rye 450 bu./day

Malt 450 bu./day

PRODUCTS:- Alcohol

Whiskey Bourbon, 300 bbls./day - 4.8 proof gals./bu.

Other

WASTES:- Quantity 1.2 M.G.D. How estimated Meter records

Beer Slop - Quantity 135,000 g.p.d. Screen Mesh #00

Back Slop 45,000 g.p.d. Thin Slop 81,000 g.p.d.

Treatment Evaporation, mixed with grain. 75,000 g.p.d. condensate to stream

Dryer 45,000 lbs. dried grain/day Rectifying Still

Tailings 2,000 g.p.d. to thin slop Spills Seldom

Analyses:- Number None Date By whom

Appearance

OUTLET: - Where to Salt River

Description:	Size & shape	Material	Location	Elevation
1.	6" circ.	V.T.	Near top of 10' bank	
2.				
3.				

Gaging possibilities Possible with built up flume

Conditions below outlet: Color

Turbidity Deposits

SANITARY SEWAGE: Disposal 2 septic tanks Persons tributary 75-80

REMARKS

Survey by H.H. Dunn Date 11-20-40

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an actual plant)

River Mileage Index No. St 20.5

Type of Plant **Bourbon Whiskey Distillery** State **Kentucky**

Name of Plant **Old Bourbon, Inc.**

Municipality **High Rock** Main Watershed **Salt River**

County **Moss** Subwatershed

Address **R.D. White Horse Pike**

Source of Information **F.W.Budd, Distiller.**

Plant Operation:- **110 hours per week.**
144 days annually (Approx. 6 mos.)
80 plant employees including warehouse employees.
6 office employees.

Seasonal Variation:-

Probable operation 6 months annually depending upon market conditions, at full capacity.

(Survey report continued on next page)

Survey by **H. H. Dunn** Date **11-20-40.**

Sewered Population Equivalent Computation:-

Factors used
B.O.D. **(1) 3,500 per 1,000 bushels** **(2) 60 per 1,000 gal.** Suspended solids **(1) 2,260 per 1,000 Bu** **(2) No record.**

Sewered population equivalent based on B.O.D. **15,200**

Sewered population equivalent based on suspended solids **6,800**

Remarks: (1) **Combined distillery wastes. (No intentional slop waste)**
(2) **Evaporator condensate waste, totaling 75,000 gallons, in additional to 2,700 gallons tailings.**

Computation by: **G.D.R.** Date **12-4-40.** Cincinnati Office

Note:- This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.

St-20.5

Old Bourbon, Inc.
High Rock, Ky.

Water Supply - Drinking - City of High Rock 100,000 G.P.D.
Industrial & Cooling -
2 deep wells . . . . . . .1,100,000 G.P.D.
Total 1,200,000 "

Raw Materials -
Corn - 70%, Rye 15%, Malt 15%.
Total 3,000 bushels at full capacity.

Products - Bourbon whiskey 300 bbls. daily. Yield 4.8 proof gallons per bushel.

Wastes - 1,200,000 G.P.D. based on meter registrations.
Beer slop - 135,000 Gals., Screen mesh double O,
Back slop. (1/3) 45,000 g., thin slop, 81,000 g.

Treatment - evaporation, mixed with grain. Condensate 75,000 g.p.d. to stream, dried grain 45,000 lbs.

Rectifying still-doubler, tailings 2,700 g. to thin slop.

Spills - seldom - Analyses - None.

Outlet - To Salt River.
6" Circ. V.T. outfalls near top of 10' bank.
Gaging possible with built up flume.

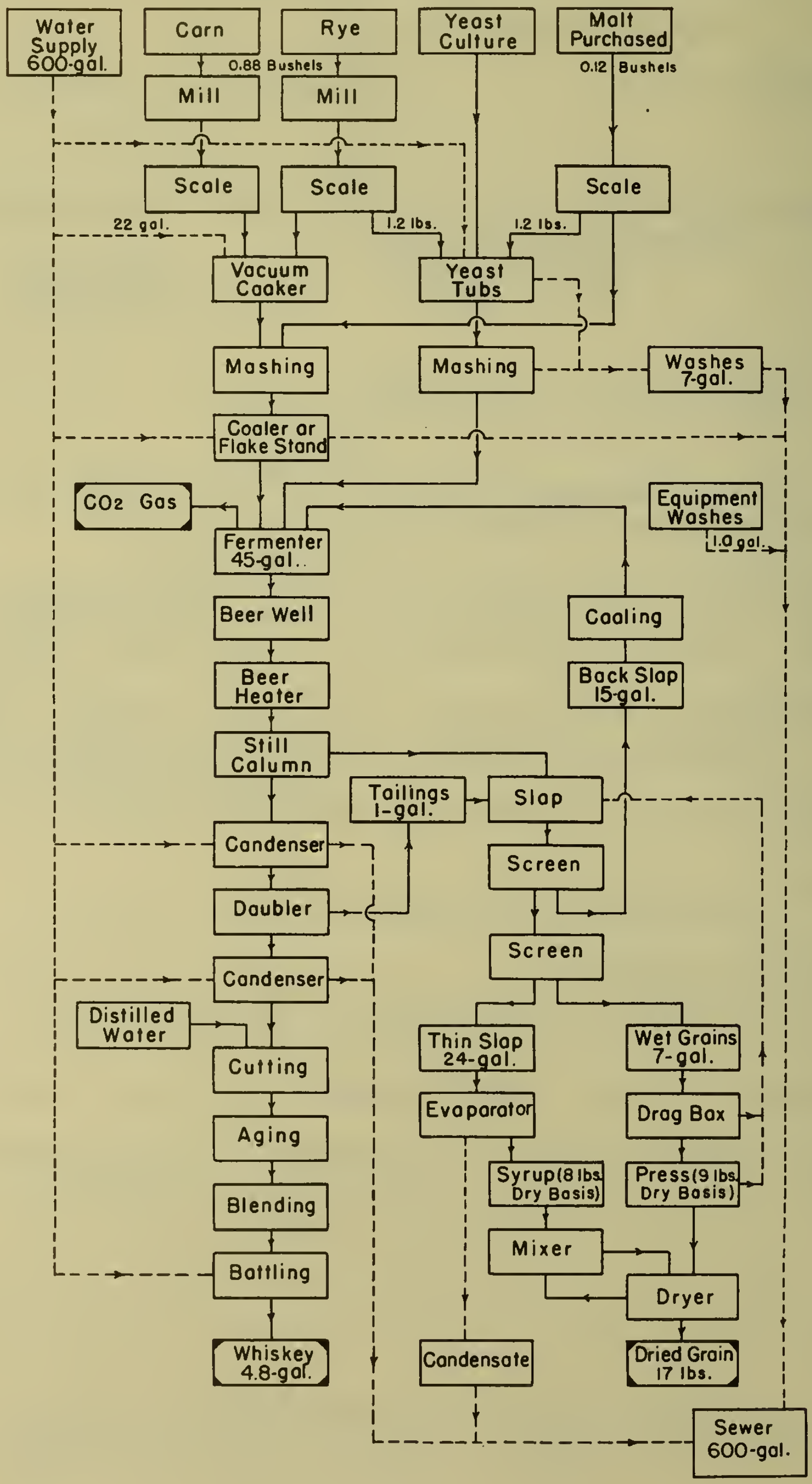
Sanitary Sewage - To two septic tanks.

Remarks - Bottling employees will number 75, three days weekly.

FLOW DIAGRAM

DISTILLERY

QUANTITIES PER BUSHEL OF GRAIN MASHED



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

MEAT

An Industrial Waste Guide to the Meat Industry

APPENDIX "VII" OF SUPPLEMENT "D"

to the

Final Report

to the

Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio.
1942

Contents

	Page
Abstract	Mt-1
Description of Process	Mt-2
Raw Materials and Products	Mt-3
Sources and Quantity of Wastes	Mt-5
Character of Wastes	Mt-7
Pollution Effects	Mt-13
Remedial Measures	Mt-13
Bibliography	Mt-21
Note Taking Form	Mt-23
Inspection Report	Mt-24
Flow Diagram - Slaughterhouse	Mt-26
Flow Diagram - Packing house	Mt-27

List of Tables

Mt-1	Meat Industry - Approximate Flows, Employees Analyses, and Sewered Population Equivalents for Stockyards, Slaughterhouses, and Packing Houses	Mt-1
Mt-2	Analyses of Major Components of Waste from Hog Packing House	Mt-11
Mt-3	Analyses of Combined Packing House Wastes	Mt-12
Mt-4	Meat Industry - Summary of Sewered Population Equivalents	Mt-13
Mt-5	Packingtown Testing Station (Chicago) - Results of Various Treatment Processes	Mt-15
Mt-6	Purification of Packing House Waste at Mason City, Iowa, for the Year 1933	Mt-16
Mt-7	Results of Activated Sludge Treatment of Packing House Wastes at Muncie, Ind.	Mt-18
Mt-8	Results of Treatment of Packing House Waste and Domestic Sewage at Sioux Falls, S. D. (March-September, 1937)	Mt-21

Abstract

The wastes from stockyards, slaughterhouses and packing houses are similar chemically to domestic sewage but are considerably more concentrated. The principal deleterious effect of these wastes on streams and other bodies of water is their deoxygenating effect.

Stockyard wastes contain animal excreta and the amount and strength of the waste varies considerably, depending upon whether the pens are covered, the presence or absence of catch basins, practice in manure removal, frequency of washing, etc.

Slaughterhouses are establishments for killing and dressing of meat. Relatively little processing of the meat or of by-products is done. Most slaughterhouses are relatively small although a few in the larger cities may kill several hundred animals per day. Packing houses are equipped to process the meat and by-products to a much greater extent. The amount of processing varies considerably from plant to plant.

Table Mt-1 shows approximate flows, analyses, and sewered population equivalents for the three types of establishments.

Table Mt-1 Meat Industry - Approximate Flows, Employees Analyses, and Sewered Population Equivalents for Stockyards, Slaughterhouses, and Packing houses.

Operation	Unit	Employees per 100 units per day	Waste Flow gal. per unit	Typical Analysis p.p.m.		Sewered Pop. Equiv. per unit per day	
				B.O.D.	Susp. Solids	B.O.D.	Susp. Solids
Stockyard	Acre	-	25,000	65	175	80	180
Slaughter-house	Ton on Hoof(1)	140	900	2,200	930	100	35
	Hog Unit	20	160	2,200	930	18	6
Packing-house	Ton on Hoof	240	(2) 4,200	900	650	190	120
	Hog Unit (1)	30	(2)550	900	650	24	14

(1) Cattle are 2.5 hog units each. Hogs, calves, and lambs are one hog unit each.

(2) Average flow figures at plants on which accurate flow data are available indicate waste flows of 6,000 gallons per ton on the hoof or 760 gallons per hog unit. With higher flows, B.O.D. and suspended solids concentrations would be lower due to dilution by the greater quantity of water used.

Meat plant wastes are amenable to biological treatment in plants of the types in common use for treating domestic sewage. Trickling filters, particularly of the type developed by Levine and associates, have proven quite successful. Activated sludge also has been used with considerable success. A number of municipal plants treat large amounts of packing house wastes with domestic sewage. Notable among these are Chicago, where the activated sludge process is used and Sioux Falls, S. D., where trickling filters and activated sludge are used. Chemical precipitation is used at a number of packing plants and slaughterhouses where less highly purified effluents are required.

Description of Process

Slaughterhouse

The slaughterhouse or abattoir is principally a killing and dressing establishment, doing little processing of by-products.

Plants vary in size from the local concerns killing a few animals per week to firms killing several hundred animals daily. Most slaughterhouses in the Ohio Basin are quite small, employing less than 5 to 10 workers.

The process consists briefly of sticking and bleeding animals on the killing floor, cattle being stunned prior to sticking. Hides, skins and pelts are removed from cattle, calves and sheep. Hair is removed from hogs by scraping after immersion of the carcass in scalding water. Insides are removed, some of which - livers, hearts, kidneys, etc. - are sent to cooling rooms to be later sold fresh as such. Carcasses are trimmed, washed, dried, and hung in cooling rooms. Hides are salted and stacked until shipped to tanners or wool processing plants. Various offal are segregated for collection and processing by specialty houses such as rendering plants, glue and gelatin works, sausage manufacturers, etc. Many slaughterhouses are now equipped to do rendering - usually for inedible greases and fertilizer tankages. The finished product of the slaughterhouse is the fresh carcass and a few fresh meat by-products such as hearts, livers, tongue,etc

Packing house

Packing house killing floor operations are,in general, carried out with more attention to recovery of saleable products.

Blood is usually collected, coagulated, and dried for edible and inedible uses. Paunch manure is generally recovered for fertilizer uses. Carcasses are trimmed, cleaned and cooled much the same as in the slaughterhouse with the exception that the packing house further processes some of the meat by cooking, curing, smoking, and pickling. The packing house is also equipped to process, to varying degrees, the "by-products" which a slaughterhouse ships out as raw by-product. Possible exceptions include tanning, wool pulling, manufacture of glues, soaps and fertilizers which are, in general, carried on by independent plants or subsidiaries under another roof. Some of the operations, in addition to those concerning processing of meat cuts, are: complete rendering of all edible and inedible materials, cleaning casings and making sausage, cleaning and drying hog hair, and canning.

Raw Materials and Product

The average weights of animals slaughtered in the United States, according to the 1937 Census Bureau statistics, are as follows:

Animal	Wt. on hoof-lbs.	Dressed wt.*-lbs.
Cattle	884	459
Calves	188	114
Hogs	218	158
Sheep, lambs	85	40

At plants surveyed in connection with the Ohio River Pollution Survey, the average live weights were approximately 10 percent lower than the above figures.

Approximate yields of total meat products and by-products are as follows:

	Percentage of live weight			
Classification	Beef	Veal	Pork	Lamb
Edible	60.1	58.9	75.8	53.9
Inedible	10.3	10.1	3.7	17.6
Shrinkage**	29.6	31.0	20.5	28.5
	100.0	100.0	100.0	100.0

---

* Not including edible organs.

** Evaporation and valueless material.

The chief product, the carcass, is marketed in various cuts of fresh, smoked, cured, pickled, and canned meats, the slaughterhouse confining its production to fresh meats while the packer produces the full line of processed meats.

The by-products of the slaughterhouse generally consist of cured hides, skins, and pelts, inedible tallows, fertilizer tankages, miscellaneous fresh offal (collected by specialty houses), pen and paunch manures shipped or carted off for fertilizer.

Packing house by-products are very numerous. Some of the principal by-products are as follows (products or uses shown in parentheses are not necessarily processed at the packing house):

(a) Hides, skins, pelts (pulled wool).
(b) Bone and bone products:
    Edible tallows (lard substitutes).
    Inedible tallows (soap, candles, lubricating oils)
    Glue stocks (glue).
    Bone meal (fertilizers, bone filter charcoals, case-hardening bone).
    Manufacturing stock (buttons, handles, etc.).
(c) Horns: (ornaments, combs)
(d) Hoofs:
    Outer portion (buttons, fertilizer).
    Inner portion - neatsfoot oil, stearine (soap, candles, glue, fertilizer).
(e) Bristles, hair: (brushes, upholstering).
(f) Intestines:
    Sausage casings.
    Tennis and musical strings, surgical ligatures.
    Ox gall (setting dyes, used in dyes, paints, laundries and dry cleaning).
(g) Fats:
    Oleomargarine.
    Stearic acid.
    (Lubricants, ointments, leather oils).
    Soap stocks (soaps, glycerine).
(h) Meat scrap and blood:
    Meat meal and blood meal stock feeds.
    Tankage (fertilizer or feeds).
(i) Glands: (medicinal preparations).

Employee - Raw Material Ratio

No. of Plants Considered	Plant	Type Kill	Employees Per 100		
			Head/ day	Tons/ day	Hog units/ day
23	Slaughterhouse	Mixed	31	140	19
7	Packing house	Mixed	37	236	28
7	do	Hogs*	37	323	37
1	do	Sheep**	5	71	4

* 90 percent or more of total kill by number.
** 88 percent of total kill by number.

Sources and Quantity of Wastes

Sources of Waste

Practically every operation connected with this industry is a source of waste through discharge or spills of process liquids and wash waters.

The chief sources of waste are as follows:

Stockyards

Slaughterhouse
- Killing floor
- Carcass dressing
- Rendering
- Hide cellar
- Cooling room

Packing house
- Killing floor
- Carcass dressing
- Rendering
- Hide cellar
- Hog hair removal and processing
- Casing cleaning
- Tripe room
- Laundry
- Glue, soap, fertilizer

Quantity of Waste

No information has been found to furnish a complete breakdown of the volumes of waste from the component operations of the slaughterhouse or the packing house, hence the volumes considered hereunder are total combined raw wastes.

Stockyards - The volume of waste from a 27-acre section of the Chicago stockyards for a 12-hour day flow was 0.623 M.G. or 23,070 gals. per acre per 12-hour day.

Slaughterhouses - Volumes of waste are small as compared with those of packing houses since the uses of water are relatively few and largely carcass washing and general cleanup washes. Unit volumes of slaughterhouse wastes are as follows:

No. of Plants	Process	Volume of waste - gals. per		
		Animal	Tons on hoof	Hog Unit
3	General slaugh.	359	867	156
6	Cattle "	395	-	157
2	Hog killing	143	-	143

Packing house - Combined waste volumes are as follows:

Number of Plants	Type of kill	Determination	24 hr. volume - gals. per		
			Animal	Ton on hoof	Hog Unit*
11	Mixed	Max.	1,470	6,724	981
		Min.	393	2,788	345
		Ave.	996	6,053	757
2	Cattle	Max.	3,091	6,240	1,235
		Min.	1,286	2,570	514
		Ave.	2,189	4,405	875
3	Hogs	Max.	676	5,520	676
		Min.	488	4,080	488
		Ave.	552	4,697	552
1**	Mixed		2,040	6,850	1,080

* Explanation given under "Sewered Population Equivalents".

** Segregated for consideration as a plant discharging paunch manure to sewer - this plant is also shown separately in the Population Equivalent Tables.

Character of Wastes

Stockyards

Stockyards appurtenant to these plants are ordinarily provided with catch basins and are usually floored and sometimes covered.

Wastes consist of liquid excreta and pen wash waters which contain manure.

Uncovered pens are subject to flushing in rainy weather with consequent leachings from manure and carrying over of manure itself to the sewer.

The character of these wastes would be expected to vary widely dependent on presence or absence of catch basins, practice in manure removal, frequency of washing, etc.

An analysis of the wastes from a Chicago stockyard is as follows:

Determination	Concentration - p.p.m.
Total susp. solids	173
Volatile susp. solids	132
Organic nitrogen	11
Amonia nitrogen	8
5-day B.O.D.	64

Slaughterhouse

Killing Floor - Blood is not saved in the smallest establishments and is drained to the sewer or catch basin. Larger houses collect, cook and press blood for sale to fertilizer manufacturers. It adds a high oxygen demand and color to the waste and the coagulated clots and particles contribute substantially to the suspended solids and general unsightliness of the waste.

Paunch manure is usually segregated from the liquid wastes and disposed of separately. At many of the rural plants it is hauled away by farmers for fertilizer or hog feed. It is frequently sold to rendering plants. A number of the city slaughterhouses dispose of paunch manure with garbage. Others incinerate it. In any case, spills and carelessness allow considerable amounts to enter the sewer. About one-fifth of the slaughterhouses in the Ohio Basin discharge all paunch manure to the sewers.

Floor washes contain blood, manure, flesh and fat particles.

Carcass Dressing - Carcass washes contain blood, flesh and fat particles from trimming.

Rendering - Many slaughterhouses render offal for inedible tallows and fertilizer tankage. Where wet rendering is practiced a tank water remaining after grease and residue are taken off must be disposed of. Larger houses evaporate this tank water to produce a sticky residue (called stick) which is mixed with the fertilizer tankage. In some houses this tank water is wasted to the sewer with its consequent load of high B.O.D. and solids content.

Where dry rendering is done the principal waste comes not from the tank - since no water is used and the entrained water evaporates - but from the draining of the hashed offal; it consists of small flesh and fat particles and intestinal contents. The pressing of the residue into cakes produces a press liquor which is ordinarily put back into the rendering vat with the next batch - this liquor is largely grease.

Wash waters, both floor and equipment, from tank rooms contribute varying amounts of pollutional material, depending on the care exercised in handling materials and on general cleanliness

Hide Cellar - Green hides are chuted to the cellar from the killing floor. Here they are piled flesh side up and sprinkled with salt. A small amount of drainage from these piles, in addition to floor wash, goes to the sewer.

Hog hair removal - Hair is loosened in a scalding tub or vat and removed by scraping. Discharge of vat waters and scrapings contribute hair, dirt, and scurf from the hog skin.

Cooling room - Drippings from carcasses, mostly blood, are contained in the floor washes. Some houses may use sawdust on the floor which is swept up periodically. Subsequent floor washes carry a large amount of suspended material.

Some average analyses representative of combined slaughterhouse wastes are as follows:

Type Kill	Concentration - p.p.m.				
	Solids			Total Nitrogen	5-day B.O.D.
	Total	Volatile	Susp.		
General	4,586	2,324	929	324	2,240
Cattle	4,099	2,049	820	154	996
Hogs	3,587	1,795	717	122	1,048

Packing house

Killing Floor - Blood is usually collected, coagulated by heating, and filtered. In some cases the filter liquid effluent is cooked in steam coil equipped vats; after cooking the liquid is pumped into the "stick" stock and evaporated and the solids added to the blood for disposal as blood fertilizer. In some plants, however, this liquor may be discharged as waste. Many of the smaller plants make no attempt to recover blood.

Paunch manure is sometimes rendered for inedible greases or sold for fertilizer. The commonest method of disposal in the Ohio Basin is to farmers or by dumping on land. About one-third of the packing houses in the Ohio Basin, including some of the largest ones, discharge paunch manure to the sewers.

Carcass dressing - This operation is, in general, no different than that carried on in the slaughterhouse, wash wastes being discharged.

Rendering - The larger packinghouses do both edible and inedible rendering and make use of various rendering processes which include high and low temperature dry rendering from which, as mentioned under slaughterhouses, the wastes discharged come from the washing and draining of hashed ingredients, and steam rendering which produces a tank liquor containing gelatin and various nitrogenous extractives. This liquor may be discharged to the sewer or it may be evaporated to "stick" and mixed with stock feed or fertilizer, depending on the materials rendered. Hot water rendering of shin bones and feet of cattle to produce neatsfoot oil stock produces tank liquors of pollutional nature.

Press liquors from the tank residues are discharged to the sewer. In some cases these liquors have a high grease content.

Hide Cellar - The wastes are similar to those from a slaughterhouse.

Hog hair removal - In the larger plants hair removal is accomplished by a mechanical scraper. The hair is removed, washed, and sold green, or further processed by soaking for 24 hours and steam boiling for 8 to 10 hours with a small amount of caustic soda. The hair is removed, steam cleaned and dried. The scalding vat, tank and wash waters containing dirt, scurf and escaped hair is discharged. Most of the smaller packing plants do not recover hair.

Casing cleaning - Casings are washed, cleaned of their contents by squeezing or pressing by hand or machine, salted, drained, resalted, and packed for shipment. Trimmings and cleanings are capable of rendering for grease extraction. The wash waters are discharged.

Tripe Room - The tripe or muscular part of the stomach of cattle is washed, scalded, scraped, and boiled, after which fatty layers are scraped off and the tripe pickled in vinegar. Wash, scalding, and cooking waters containing grease and suspended matter, and spent pickle liquors are discharged.

Sausage Room - Process consists of preparing fillings from meat, and stuffing the casings. Utensil and floor washes are discharged. Much small offal is reported to reach the sewer from the sausage room of the small factory.

Laundry - The laundries of the large plants are of considerable size. An analysis of this waste is included with the tabulation of analyses of hog plant wastes.

Glue Stocks - The manufacture of glue is usually carried out in a separate plant. However, a gelatin may be produced at the packing house for sale to glue works as a raw material. This gelatin is produced by extracting the gelatinous matter by rendering of heads, feet, snouts, bones, ears, tendons, hide trimmings, etc. The wastes discharged consist of wash and steep waters prior to rendering.

Soap - The manufacture of soaps as such is confined to some of the largest houses. The average packing house produces the inedible greases sold to the soap manufacturers. The wastes produced from the manufacture of such greases is covered under renderin

Fertilizers - The production of fertilizers as such has lost some of its importance in the packing house with the advent of dry rendering which enables production of higher grade tankages which are used more for stock feed, than for fertilizer. The fertilizer industry, once largely a packing house operation, has become more the province of the chemical industry, and packing house fertilizer stocks are shipped for use by fertilizer plants.

The character of the major components of the waste of a hog packing house is indicated in Table Mt-2.

components of waste from Hog Packing House*

	Concentration - p. p. m.							
	Solids		Nitrogen		Cl as NaCl	O.C.	5-day B.O.D.	pH
	Total	Susp.	Org.	NH3				
Killing Dept.	1,840	220	134	6	435	500	825	6.6
Blood and tank water	44,640	3,690	5,400	205	6,670	-	32,000	9.0
Scalding tub	13,560	8,360	1,290	40	640	4,300	4,600	9.0
Hog dehairing	1,540	560	158	10	290	620	650	6.7
Hair cook water	4,680	80	586	30	290	-	3,400	-
Hair wash water	7,680	6,780	822	18	230	1,680	2,200	6.9
Meat cutting	2,840	610	33	2.5	1,620	260	520	7.4
Gut washer	22,600	15,120	643	43	360	-	13,200	6.0
Curing room	26,480	1,800	83	12	19,700	2,520	2,040	7.3
Curing room showers	34,100	1,720	255	25	29,600	875	460	6.7
Cured meat wash	9,560	920	109	17.5	6,200	950	1,960	7.3
Pickle	140,000	-	2,750	37	77,800	-	18,000	5.6
Sausage and misc.	11,380	560	136	4	880	460	800	7.3
Lard dept.	820	180	84	25	230	200	180	7.3
By-products	4,000	1,380	186	50	1,330	970	2,200	6.7
Laundry	18,620	4,120	56	5	-	780	1,300	9.6

* Iowa Engineering Experiment Station Bulletin No. 130.

Analyses of the combined raw wastes from packing houses are shown in Table Mt-3. Most of these plants are in Chicago.

Table Mt-3 Analyses of Combined Packing House Wastes

Number of Plants	Concentration - p.p.m.				
	Suspended Solids		Nitrogen		5-day B.O.D.
	Total	Volatile	Org.	NH_3	
28	699	597	116	25	953
4	398	-	98	-	587
1	467	-	68	-	550
1	708	613	-	-	758
1	720	-	-	-	955
1	233	195	-	-	372
1	534	449	71	12	1,240
1	665	658	167	14	1,634
Average*	645	582	113	24	909

* Average weighted by plants.

Sewered Population Equivalents - Table Mt-4 shows approximat sewered population equivalents on the basis of B.O.D. and Suspended Solids for stockyards, slaughterhouses and packing houses. These are based on a per capita discharge of .167 pounds of 5-day B.O.D. and .2 pounds of suspended solids per day. Analyses indicate that the wastes from hog packing are greater per pound of animal than those from cattle packing. The method of evaluatig the wastes from a mixed kill in terms of hog units assumes that the wastes per head of cattle is equivalent to that from 2.5 hogs, while calves and lambs are each equivalent to a hog. These factors were suggested by Milling and Poole. Other authorities have used other factors. The sewered population equivalents shown on the basis of live weight are somewhat more reliable for use when an appreciable portion of the pack is cattle. When the kill is primarily hogs, the hog unit basis is better. The wide variations in the sewered population equivalents per animal or per ton from various plants makes differentiation between mixed packing, cattle packing and hog packing an unwarranted refinement

Table Mt-4 Meat Industry - Summary of Sewered Population Equivalents

Type of Plant	Sewered Population Equivalent					
	Per Acre		Per Ton on Hoof per Day		Per Hog Unit per Day	
	B.O.D.	S.S.	B.O.D.	S.S.	B.O.D.	S.S.
Stockyard	80	180	-	-	-	-
Slaughterhouse	-	-	100	35	18	6
Packing house	-	-	190	120	24	14

Pollution Effects

Meat plant wastes are quite similar to domestic sewage in their composition and in their effects upon receiving bodies of water. The danger from pathogenic organisms in packing house or slaughterhouse wastes, however, is slight. Oxygen depletion, sludge deposits, discoloration, and general nuisance conditions are the principal deleterious effects of meat plant wastes.

Remedial Measures

Plant Practices

Various plant practices in more or less common use tend to reduce the quantity or strength of wastes from meat plants. Most of these practices are profitable, at least in the larger plants. Among them are blood recovery, utilization of paunch manure, grease recovery, utilization of tank waters and tankage press liquors, etc. The extent to which such practices are employed effects greatly the pollution load from the plant. Baffled basins or traps on waste lines are in common use for grease recovery but the efficiency of the units varies considerably. Many grease traps are inadequate in size and receive little attention. Blood recovery practices also vary widely. Some plants recover none of the blood, some recover only the first blood, while at other plants relatively little blood enters the sewers. In most plants where paunch manure is recovered a certain amount of the waste reaches the sewers.

No data are available as to the possible reduction in waste load that can be effected by recovery of by-products, careful segregation of solid wastes, and generally good housekeeping methods but the reduction must be considerable.

Treatment

Chicago Experiments - The most extensive studies of treatment for meat plant wastes were made by the Sanitary District of Chicago through the operation of the Packingtown Testing Station from 1912 to 1914 and from 1915 to 1918. Other extensive studies of such wastes have been made by Levine and his associates Halvorsen, and others. All of the standard methods of waste treatment have been investigated and a number of special methods have been developed. Both trickling filters and activated sludge have been found suitable for treatment of meat plant wastes and chemical precipitation is used in a number of plants where lower reductions in B.O.D. are sufficient.

The following is abstracted from a summary of the Packingtown studies by Mohlman.

Treatment processes studied included fine screening, sedimentation, chemical precipitation, trickling filters and activated sludge.

The results of these extensive studies are as follows:

Screening - by rotary wire mesh screen remove coarse materials such as hair, flesh, paunch manure and floating solids. Frequent clogging of screens necessitated washing with hot water and soda ash. Removals of 9 percent suspended solids on 20 mesh screen and 19 percent on 30 mesh screen were reported. There was no appreciable B.O.D. reduction.

Sedimentation - in an Imhoff tank was found the most satisfactory process for clarification. Chemical precipitation, while removing more suspended solids, produced an excessive volume of sludge which was ill-smelling and hard to dry. Imhoff removals were approximately 65 percent suspended solids, 35 percent B.O.D. with detention periods of 1 to 3 hours, with a sludge containing 90 percent moisture.

Filtration - on trickling filters consisting of $5\frac{1}{2}$ feet of $1\frac{1}{4}$ to 2 inch stone over 6 inches of 2 to 4 inch stone, at rates varying from 0.6 to 1.0 m.g.a.d., gave satisfactory nitrified effluents which could be well clarified by secondary sedimentation. The filters were reported to give little trouble from pooling, flies, or odors - they unloaded continuously. Removals were 81 percent B.O.D. (88 percent overall).

Activated Sludge - gave a satisfactory effluent with 9 hours aeration and 3.5 cu.ft. air per gallon. Nitrates ran 5 to 7 p.p.m. in summer but in winter it was necessary to increase air rates up to 4 or 5 cu. ft. per gallon and even at this high rate nitrates were not produced. The suspended solids and B.O.D. removals were higher than those of the settled trickling filter effluents.

Table Mt-5 shows typical and representative analyses of the applied raw waste and the effluents produced follows:

Table Mt-5 Packingtown Testing Station (Chicago) - Results of Various Treatment Processes.

Determination	Effluent - p.p.m.				
	Raw Waste	Screen	Imhoff Tank	Trickling Filter	Activated Sludge
Ammonia nitrogen	22	22	29	16	10
Organic "	79	75	60	20	10
Nitrite "	0.5	0.5	0.2	2.2	1
Nitrate "	3.0	3.0	1.7	16.4	5
Oxygen consumed	268	240	180	50	-
Chlorine	1100	1100	1100	1100	1100
Alkalinity	212	212	240	200	-
Suspended solids	605	515	210	75	30
B.O.D. (10 day)	990	930	630	120	50

Double Filtration - The studies by Levine and his associates at Mason City, Iowa, led to the construction, in 1929, of a plant providing double filtration to replace an activated sludge plant which had failed due to a greatly increased load and wide fluctuations in the strength and character of the wastes. The plant provides primary clarification with two hours detention, primary filtration at a rate of 3,000,000 gal. per acre per day, on a washable filter four feet deep with ½" to 1" dolomite filter media, intermediate clarification with 2 hours detention, secondary filtration at a rate of 1,500,000 gal. per acre per day on an eight foot deep filter with 1" to 3" dolomite filter media, and final sedimentation. Table Mt-6 shows the results of treatment during 1933. The average volume treated was about 600,000 g.p.d. as compared with a design flow of 750,000 g.p.d.

Table Mt-6 Purification of Packing House Waste at Mason City, Iowa, for the Year 1933.

	Raw Waste	Primary Clarifier Effluent	Intermediate Clarifier Effluent	Final Clarifier Effluent
Org. N.	150.4	97.9	54.3	12
NH_3	46.5	63	81.3	35
B.O.D.	1,437(±402)	1,020(±253)	534(±232)	82(±81)
No. of samples for B.O.D.	201	197	198	202
Over-all percent reduction				
Org. N.	-	34.7	63.8	92
NH_3	-	-	-	24.7
B.O.D.	-	29.0	62.8	94.3

A plant similar to the Mason City plant has been installed by the Armour Packing Company at West Fargo, N.D. The following data are taken from a description of the plant by Howson. The treatment process includes the following steps: (1) Fine screens, (2) grit removal, (3) grease flotation, (4) flocculation, (5) primary settling, (6) washable primary trickling filters, (7) secondary settling, (8) final trickling filters with two units which may be operated in series or in parallel,(9) final settling, and (10) discharge to river over aerating cascades. Although essentially like the Mason City plant, the West Fargo installation includes a number of improvements and changes which have been found desirable as a result of the experience with the earlie plant.

The grit chamber and settling tank each provide 30 minutes detention and together remove about 90 percent of the settleable solids and 35 to 40 percent of the B.O.D. The grease flotation tank provides 15 minutes detention and is divided into aeration and coalescing compartments by an inclined baffle. The flocculation compartment provides 40 minutes detention and is equipped with three paddle type flocculators in series. Flocculation without the addition of chemicals increases the B.O.D. removal through the tanks by about 5 percent. In order to equalize the flow through the secondary devices, a storage tank with a capacity of 20 percent of the day's flow is provided.

The primary filters are six feet deep and are equipped with both air and water wash systems. The filter media is 1"-2" granite and the operating rate is about six m.g.a.d. Used wash water flows to a storage tank from which, after settling, the water flows to the secondary clarifier and through the rest of the plant. The filters are washed every 2 or 3 weeks. In the intervening period the wash water settling tank is used for sludge thickening. The primary filters, together with the primary and secondary clarifier, have consistently reduced the B.O.D. of the raw wastes from 1,000 p.p.m. to 250-350 p.p.m. when loaded at rates of 5,000 to 6,000 pounds of B.O.D. per day. Secondary settling is in a Dorr clarifier with a detention period of one hour. The final filters are conventional trickling filters six feet deep and dosed at a rate of about 1,400,000 g.a.d. when operated in parallel. The final filters are ordinarily operated in parallel. Overall reductions of more than 95 percent of the B.O.D. have been accomplished consistently.

Several additional plants providing high rate washable filters have recently been constructed at packing houses at South St. Paul, Minn. These plants do not have final filtration.

High Rate Filtration - The Hormel plant at Austin, Minn. has abandoned its chlorine precipitation plant, built in 1931, in favor of high-rate filtration of the type developed by Halvorson.

Activated Sludge - Results of tests by the Indiana State Board of Health on the activated sludge treatment plant of the Kuhner Packing Co., Muncie, Ind. in 1937 and 1938 have been reported in a paper by Milling and Poole, from which the following is extracted.

The plant cost $41,000, has a design capacity of 200,000 to 500,000 g.p.d. estimated to treat the process wastes resulting from packing operations of 350 to 500 hog units per day. This plant has several unique features including pre-aeration of incoming wastes, intermittent intensity of aeration in the main aeration units with provisions for occasional aeration in the final settling tank, split flow of return sludge, and intermixing of waste sludge in the pre-aeration tank and primary settling tank.

Raw wastes are aerated 30 to 60 minutes in the presence of activated sludge in a pre-aeration tank. An air lift consisting simply of a hood over two diffuser plates raises the effluent to the primary settling tank. This tank is equipped with straight line sludge removal apparatus with skimmer. Use is again made of the air lift to raise effluent from weir trough to aeration tanks. The spiral flow aeration tanks, two in number, each having two channels 48 by 22.5 ft. and 10 ft. deep, can be operated in series up to full four passes. Final clarification is provided by a center inlet, radial flow settling tank equipped with rotary continuous sludge removal apparatus. An air lift removes the sludge to the pre-aeration and aeration tanks. At the time of the tests (1937 and 1938) sludge was pumped from primary tank by displacement pump or air lift directly to the old sand beds. It was expected that a digestion tank would be provided in the near future. Compressors, pump, control equipment, laboratory and office are housed in a brick building.

In times of abrupt changes in loading and temperature, bulking occurred in the final tank. To prevent discharge of sludge and relieve the condition the final tank was lowered several inches by shutting off the influent and applying air to the final tank for 10 minutes every 2 hours.

About 90 percent of the return sludge is passed to the aeration tanks and 10 percent to the pre-aeration tanks. No mention was made of aeration tank foaming.

Results of operation during the sampling periods are shown by the following table. The wastes ordinarily result from packing operations with a mixed kill of cattle, hogs, calves, and lambs. At the time of the tests the kill was cattle and hogs.

Table Mt-7 Results of Activated Sludge Treatment of Packing house Wastes at Muncie, Ind.

Sample	Raw Waste p.p.m.		Reductions in percent			
			By primary Clarifier		Overall	
	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.	Susp. Solids	B.O.D.
9 hr. composite	1016	940	58	29	98.7	99.5
24 " "	-	980	-	-	-	98.3
24 " "	400	353	80.5	49	98.6	98.4
Average	708	758	51.6	44	97.5	98.8

About 4.25 cu. ft. of air was used per gallon of waste treated and about 780 cu. ft. of air per pound of B.O.D. reduction. The B.O.D. of the raw waste averaged 1,187 pounds per day or about 3.14 pounds per hog unit. The cost of operation based on the first six months operation including two operators, power, maintenance, interest and depreciation was estimated at $21.93 per day or 5.5 cents per hog unit on the basis of 400 hog units per day.

Chemical Precipitation - A number of precipitants have been used in various plants treating packing house wastes. The use of superchlorination for the precipitation of proteins as practiced at Austin, Minn. has been abandoned because of cost, the toxicity of the sludge, and the necessity of excluding much of the waste from the treatment process.

At Phoenix, Ariz. a packing plant uses ferric chloride made from wire and chlorine. B.O.D. reductions from 1,448 to 188 p.p.m. and suspended solids reductions from 2,975 to 167 p.p.m. are obtained, using 1,000 pounds of wire and 1,150 pounds of chlorine per million gallons. Operating costs are $68 per million gallons but the effluent is sold for irrigation, grease recovered, and sludge gas utilized and the net cost is said to be about $25 per million gallons.

At Madison, Wis., two-stage chemical precipitation, using zinc chloride and alum followed by settling, lime treatment and secondary settling has proved successful. Grease is recovered; the sludge dewatered on a vacuum filter and used for fertilizer. The effluent is clear and straw colored. B.O.D. reductions from about 1,600 to 200 p.p.m. and suspended solids reductions from about 1,200 to 80 p.p.m. are reported. This process was developed by Domogalla and is patented.

Eldridge has found fill and draw chemical precipitation, using chlorine and ferric chloride, well suited to the needs of small slaughterhouses. He suggests segregation of all unpolluted water, recovery of as much blood, paunch manure, etc. as possible prior to treatment. The coagulation and settling tank should be large enough to hold one day's flow and should be equipped with a stirring mechanism. Chlorine gas should be applied through diffusers, the flow of chlorine being regulated by a needle valve in the chlorine feed line. About one-eighth of a gallon of 40 percent ferric chloride is used per 1,000 gallons of waste. The sludge is sterile and can be dried on sand beds or disposed of on land. Such a plant constructed at the Grand Rapids Packing Co., to treat 5,000 gallons of waste per day cost $500, exclusive of housing, and operating charges were $1.50 per day. The B.O.D.

was reduced from 2,700 to 310 p.p.m. and the suspended solids from 1,320 to 178 p.p.m. The principal disadvantage of this type of treatment is the danger of using chlorine without relatively expensive chlorine control machines.

Treatment with Municipal Sewage - Since meat plants are concentrated in the larger cities, the commonest method of treating their wastes is in municipal treatment plants. Chicago is the largest center of meat packing in the world and the wastes from these establishments are being treated successfully by the activated sludge process. Other cities treat varying amounts of meat plant wastes by plain sedimentation, chemical precipitation, trickling filters, activated sludge, and combinations of these methods. Pretreatment of the packing house waste prior to admission to the city sewers is required in a number of places. Screening and clarification are the most common methods of pretreatment but in a few instances more complete treatment such as chemical precipitation, grease removal, or chlorination is required.

At Sioux Falls, S.D. where packing house wastes are about 76 percent of the total waste load, a municipal treatment plant including chemical precipitation, trickling filters and activated sludge has been successful in producing a highly purified effluent. Experiences in treating these wastes have been described by Bradstad and Bradney. The following data are abstracted from their article. An earlier trickling filter plant operated satisfactorily with overall removals of 80 to 85 percent of the B.O.D. and suspended solids but the residual B.O.D. polluted the receiving stream seriously. After considerable experimental work, the plant was remodeled to provide chemical precipitation of the packing house wastes, separate sedimentation of the domestic sewage, followed by trickling filters, activated sludge treatment (about 5 hours aeration), and final sedimentation. Considerable difficulty with floating sludge in the final tanks was experienced due to denitrification of the effluent. This was controlled by regulating the dissolved oxygen content in the aerator within the narrow range which would prevent both floating sludge and bulking. In order to do this effectively it was necessary to overcome the wide fluctuations in flow to the aerator. This was done by regulating the rate of pumping from the filter to the aerator and,although the filter effluent backed up in the filter gallery, this had no detrimental effect on the efficiency of the units. The following table shows the average results during a seven-month period (March-September, 1937) when the wastes were separately clarified, filtered at 4.0 m.g.a.d. during the day and 2.0 m.g.a.d. at night, aerated, and settled. No chemicals were used in the flocculation.

Table Mt-8 Results of Treatment of Packing House Waste and Domestic Sewage at Sioux Falls, S. D. (March-September, 1937).

	Suspended Solids		5-Day B.O.D.	
	p.p.m.	% removal (overall)	p.p.m.	% removal (overall)
Packing house - raw*	720	-	955	-
Domestic - raw	403	-	325	-
Combined - raw	532	-	575	-
Pack. Primary effluent	321	55.4	568	40.5
Dom. " "	120	70.2	149	54.2
Comb. " "	209	60.7	322	44.0
Trickling Filter "	200	62.4	187	67.5
Final "	9.9	98.1	10.6	98.2

* Packing house waste screened and settled briefly before discharge to municipal sewers.

Bibliography

(1) Bradstad, R. E., and Bradney, L. Packing House Waste and Sewage Treatment at Sioux Falls, South Dakota. Sewage Works Journal, 9, 959, (1937).

(2) Calvert, C. K., and Parks, E. H. The Population Equivalent of Certain Industrial Wastes. Sewage Works Journal 6, 1159, (1934).

(3) Chicago, Sanitary District of. Results of Sampling and Gaging Studies of Various Industrial Wastes (1935-38) unpublished.

(4) Dilling, A. W., and Pearse, L. Report on Industrial Wastes from the Stockyards and Packingtown in Chicago, 1921.

(5) Eldridge, E. F. Industrial Waste Treatment Processes and Plant Design. Michigan Engineering Experiment Station Bulletin No. 82 (1938).

(6) Fullen, W. P., and Anderson, E. N. A New Treatment for Meat Packing Wastes (Superchlorination). Public Works, 62, No. 7, 25, (July, 1931).

(7) Hoskins, J. K., Ruchhoft, C. C., and Williams, L. G. A Study of the Pollution and Natural Purification of the Illinois River. U. S. Public Health Service Bulletin No. 171, (1927).

(8) Howson, L. R. Packing House Waste Treatment (West Fargo, N. D.). Water Works and Sewerage, 87, 217, (1940).

(9) LeBosquet, M., Jr., and Symons, G. E. Buffalo Sewer Authority, unpublished data.

(10) Levine, Max. Experiments on the Purification of Creamery and Packing House Wastes. American Journal of Public Health, 25, 171, (1935).

(11) Levine, M., Nelson, F. G., and Dye, E. Experiments on Purification of Packing House Wastes at Mason City, Iowa. Iowa Engineering Experiment Station Bulletin 130, (1937).

(12) Michigan Stream Control Commission. Second Biennial Report (1933-34).

(13) Milling, M. A., and Poole, B. A. Disposal of Packing House Waste, The Kuhner Packing Company, Muncie Indiana. Sewage Works Journal, 10, 738, (1938).

(14) Mohlman, F. W. The Growing Importance of Industrial Waste Disposal. Water Works and Sewerage, 87, 93, (1940).

(15) Mohlman, F. W. Treatment of Packing House, Tannery, and Corn Products Wastes. Industrial and Engineering Chemistry, 18, 1076, (1926).

(16) Ohio River Pollution Survey files.

(17) Tomhave, W. H. Meat and Meat Products.

(18) U. S. Public Health Service, unpublished data.

(19) Wisner, G. M. Report on Industrial Wastes from the Stockyards and Packingtown in Chicago, (1914).

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

I-7
Rev.8-39

MEAT INDUSTRY WASTES (Not an Actual Plant)

Plant Abbatt - Orr Packing Co. State W. Va. Ref.No. K 127

City Bardell County Pasey Main Watershed Kanawha

Address 864 East Main St. Principal Product Meat

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	40	300	300
Maximum			

Seasonal variation June-Oct. 96%, Oct.-Feb. 110 %, Feb.- June 94% of ave. Killing days per week

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking				
Industrial	City	329,000		None
Cooling	River			

KILL:- Per Year

	Beef	Calves	Lambs	Hogs
Normal	240,000 lbs/day - 26,000 lbs.	62,000 lbs./day	45,000 lbs/day	40,000 lbs/day
1938	240,000 lbs/day			
Maximum				

If available, give live weights under remarks.

U. S. Inspected? 100 % Local Inspection? No

WASTES:- Quantity 329,000 g.p.d. + cooling How estimated Meter records

Blood recovered Yes

Method Cooled and mixed with tankage - Liquor discharge to Sewer

Paunch Manure Dumped in tanks - Overflow liquor to sewer - solids shipped

Rondering wet - tank liquors discharged to sewer (No. I sewer)

Segregation of Strong Wastes

Difficulties

Grease traps Yes - 35 ft. x 10 ft. - 3 ft. deep - receives killing floor, casing and sausage dept. and tank house wastes

Other treatment None

Analyses: - Number None Date By whom

Appearance Slight red

Stock Pens: Area Stock capacity

OUTLET: - Where to Direct to Kanawha River thru 3 outlets

Description:	Size and shape	Material	Location	Elevation
1.	15" circular	Vit. Tile	Grease trap effluent	
2.	10" "	" "	Pens (catch basin on line)	
3.	8" "	" "		

Gaging possibilities Good - outlets exposed, C. B and Grease trap

Conditions below outlet: Color

Turbidity Slight grease on river Deposits None

SANITARY SEWAGE: Disposal in No. 3 - 8" sewer Persons tributary 330

REMARKS No evaporators, tankage press liquor discharged (No. I sewer) cooling water to separate sewer (not listed above)

Survey by A. K. Brown Date July 11 - 1939

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an actual Packing House

River Mileage Index No. K 127

Type of Plant Packing House State W.Va.

Name of Plant Abbott-Orr Packing Co.

Municipality Bardell Main Watershed Kanawha

County Dosey Subwatershed ------

Address 864 E. Main St.

Source of Information John Smith, Supt.

Plant Operation:-

300 plant employees, 30 office.
40 hr. per week, 300 days per year.

Seasonal Variation:-

June-Oct. 96% of ave.
Oct.-Feb. 110% of ave.
Feb.-June 94% of ave.

(Survey report continued on next page)

Survey by A. K. Brown Date 7-11-39

Sewered Population Equivalent Computation:-

Factors used

B.O.D. 190 Suspended solids 120

Sewered population equivalent based on B.O.D. 25,000

Sewered population equivalent based on suspended solids 16,000

Remarks: Wet rendering. Tankage press liquor to sewer.
P.E. based on 110% of ave. kill.

Computation by: W.Wimple Date 10-14-39 Cincinnati Office

Note:- This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.

Abbott-Orr Packing Co.
Bardell, W.Va.

Water Supply - 329,000 g.p.d. from city supply for drinking and industrial purposes. No additional treatment. Cooling water from Kanawha River without treatment. Quantity unknown.

Kill - Average 240,000 lbs. live weight per day.

Number per year -		
	Beef	26,000
	Calves	62,000
	Lambs	45,000
	Hogs	140,000

All U. S. inspected. No local inspection.

Wastes - 329,000 g.p.d. plus cooling water (estimated from meter readings on water supply).

Blood recovered, mixed with tankage.

Paunch manure dumped in tanks. Overflow liquor to sewer. Solids shipped. Wet rendering. Liquor to #1 sewer.

Grease trap 35' x 10' x 3'. Receives wastes from killing floor, casing and sausage department, and tank house.

No treatment, no analyses.

Outlet - Three outlets direct to Kanawha River.
#1 - 15" tile - grease trap effluent.
#2 - 10" tile - stock pens (catch basin on line)
#3 - 8" tile.
Good opportunity for gaging. Outlets are exposed.

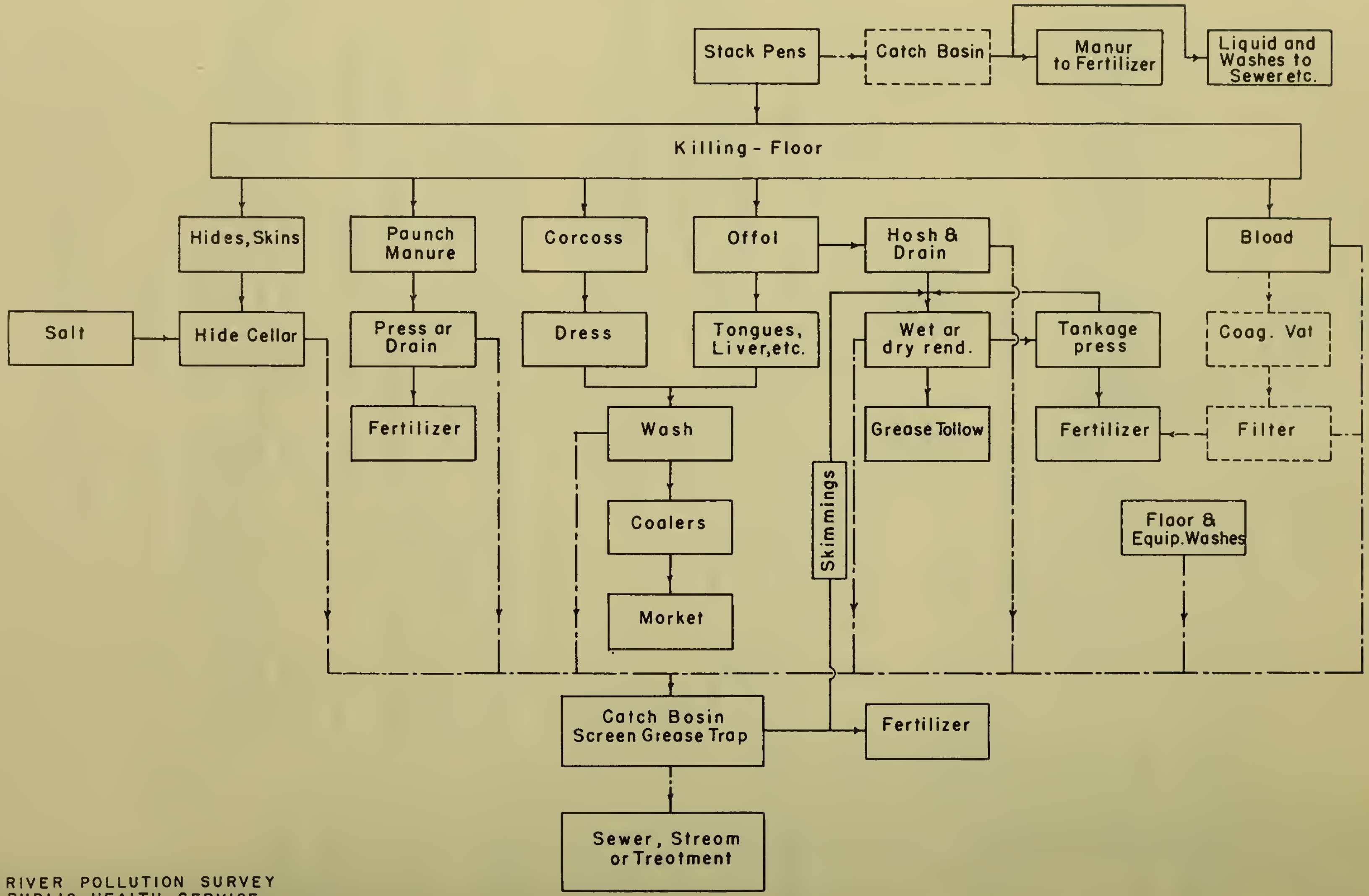
Sanitary Sewage - To #3 sewer. 330 persons tributary.

Remarks - Slight red color and some grease noticeable in river below outlets. Storm drainage and cooling water to ditch west of plant. No evaporators, tankage press liquor discharged to #1 sewer.

FLOW DIAGRAM

SLAUGHTERHOUSE

(CATTLE)

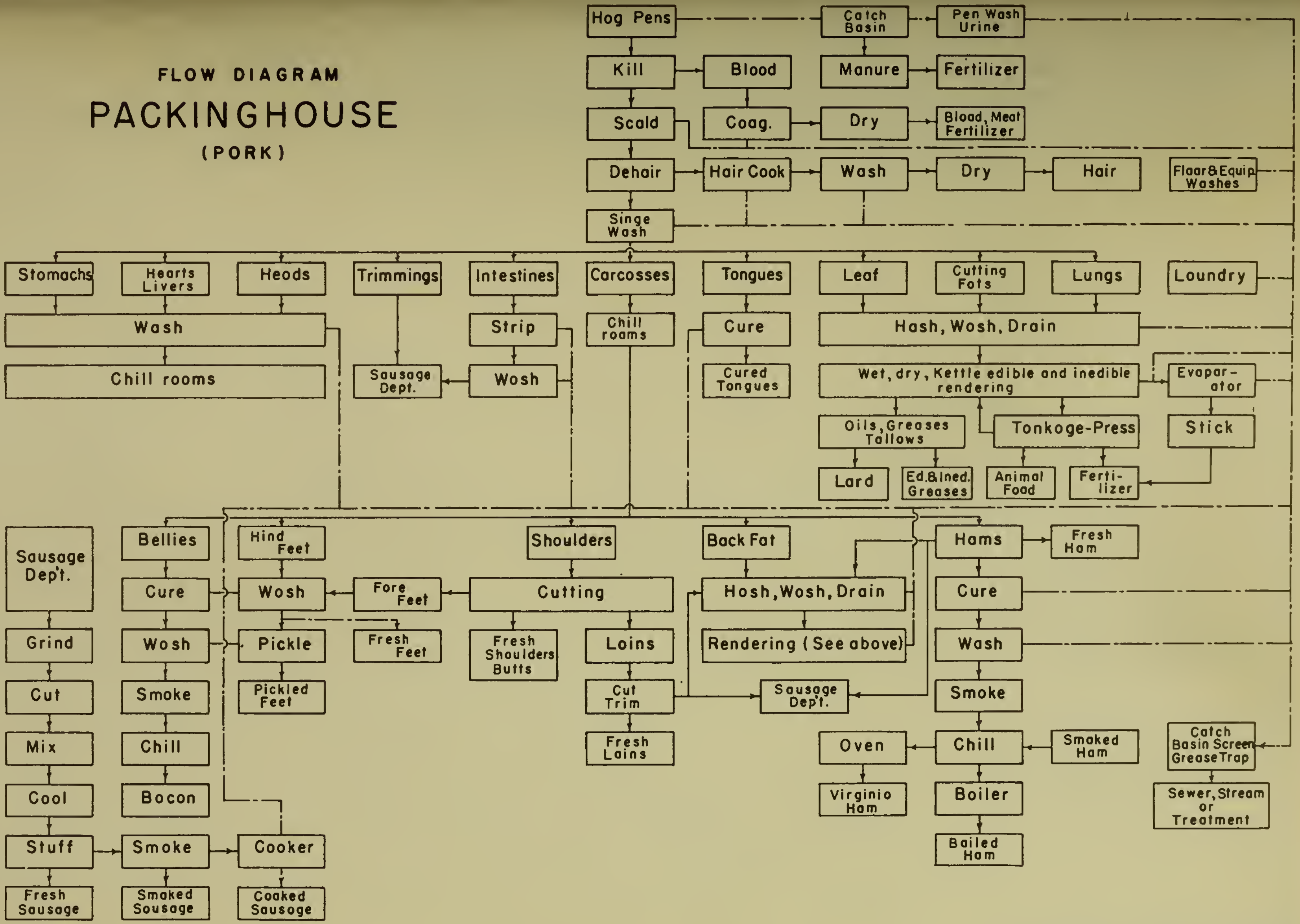


OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

FLOW DIAGRAM

PACKINGHOUSE

(PORK)



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

MILK

An Industrial Waste Guide to the Milk Processing Industry

APPENDIX "VIII" OF SUPPLEMENT "D"

to the

Final Report

to the

Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract Mk-1
Description of Process. Mk-2
Raw Materials and Products. Mk-6
Sources and Quantity of Waste Mk-7
Character of Wastes Mk-9
Pollution Effects Mk-13
Remedial Measures Mk-13
Bibliography. Mk-30
Note-Taking Form Mk-32
Inspection Report Mk-33
Flow Diagram Mk-35

List of Tables

Mk-1 Typical Analytical Results and Sewered Population Equivalents. . Mk-2
Mk-2 Ratio of Products to Raw Material. Mk-6
Mk-3 Ratio of Employees to Raw Milk Intake. Mk-7
Mk-4 Ratio of Waste Volume to Raw Milk Intake Mk-8
Mk-5 Average Analyses of Milk and By-Products Mk-9
Mk-6 Typical Analytical Results of Milk Plant Wastes. Mk-11
Mk-7 Volume and Strength of Milk Product Wastes Mk-11
Mk-8 Typical Sewered Population Equivalents - B.O.D.. . . . . Mk-12
Mk-9 Average Sewered Population Equivalents - B.O.D. and Suspended Solids Mk-13
Mk-10 Summary of Drip Saver Performance, Pennsylvania. Mk-14
Mk-11 Summary of Septic Tank Performance, New York Mk-17
Mk-12 B.O.D. Removals on Various Filtering Media Mk-20
Mk-13 Performance of Continuous High Rate Trickling Filter Mk-21
Mk-14 Trickling Filter Performance, Milk Receiving Station and Powder Plant, New York. Mk-23
Mk-15 Trickling Filter Performance, Condensed Milk Plant, Ohio Mk-23
Mk-16 Trickling Filter Performance, Condensed Milk Plant, Wisconsin. . Mk-24
Mk-17 Performance of High Rate Recirculating Trickling Filter Mk-25
Mk-18 Performance of Activated Sludge Plant, Creamery and General Dairy, Ohio. Mk-26
Mk-19 Performance of Mallory Process, General Dairy. Mk-27
Mk-20 Operating Results of Guggenheim Process, Cheese Plant, Michigan Mk-28
Mk-21 Operating Results of Guggenheim Process, Cheese Plant, Ohio. . . Mk-29
Mk-22 Installation and Operating Costs - Milk Waste Treatment Plants . Mk-29

Abstract

A plant handling or processing milk and its products may be generally classified as a receiving station, bottling works, cheese factory, creamery, condensery, dry milk plant, ice cream plant, or general dairy. The last group consists of combinations of some or all of the other types of plants.

Wastes are made up, for the most part, of various dilutions of whole milk, skim milk, buttermilk, and whey from accidental or intentional spills; drippings allowed to waste by inefficient processing equipment, methods, or operations; washes containing alkali or other chemicals used to remove milk, milk products, and partially caramelized material from cans, bottles, tanks, vats, utensils, pipes, pumps, hot wells, pans, coils, churns, and floors; and process washes of butter, cheese, casein, and other products.

Fresh wastes may be acid or alkaline. Where receiving waters cannot provide sufficient oxygen for aerobic decomposition, the lactose is converted to lactic acid and the wastes become sufficiently acid to precipitate the casein. The heavy black sludge deposits and strong pigpen odors caused by the putrefying casein characterize milk waste pollution. Typical analytical results and sewered population equivalents are shown in Table Mk-1.

Remedial measures may generally be classified as by-product recovery and waste treatment. The first group includes the recovery of whole milk by the installation of drip savers; the processing of skim milk, whey, and buttermilk into powder, casein, albumin, or lactose; and conversion of waste products into stock feed.

The chief treatment methods in use today are dilution, irrigation, septic tanks, trickling filters, activated sludge, and the Guggenheim process. Dilution or irrigation are usually sufficient where plants are small and isolated. The use of trickling filters has been found to be the most widely applicable method of treating milk wastes, averaging 80 to 90 percent reduction in 5-day B.O.D. Activated sludge has had limited use. B.O.D. removals by this process average 90 percent or more but close supervision and control are required. One of the newest developments is the "Mallory" process, utilizing activation followed by aeration. The treatment units are prefabricated and easily set up where needed. Data available indicate a high

efficiency, based on B.O.D. removals. The Guggenheim process, combining chemical precipitation and aeration, is finding limited application, chiefly at cheese plants. Care must be taken to exclude whey since the process is upset by even small amounts. High efficiencies can be obtained under very strict control and supervision.

Table Mk-1 Typical Analytical Results and Sewered Population Equivalents

Type of Plant	Sewered Population Equivalent		Typical Analytical Results	
	Biochemical Oxygen Demand	Suspended Solids	Biochemical Oxygen Demand	Suspended Solids
	Per 1,000 Pounds of Milk Received		Parts per Million	
Receiving Station	4	2	500	-
Bottling Works	6	3	-	-
Cheese Factory	16	9	1,000	750
Creamery	6	3	1,250	660
Condensery	7	4	1,300	750
Dry Milk Plant	6	3	480	-
General Dairy	10	5	570	540
	per 100 Gallons			
By-products*				
Whey	160	-	32,000	-
Buttermilk	320	-	64,000	-
Skim Milk	365	-	73,000	-

* Additional when discharged to sewer.

Description of Process

Plants handling or processing milk and milk products may be generally classified as:

(a) Receiving Station
(b) Bottling Works

(c) Cheese Factory
(d) Creamery
(e) Condensery
(f) Dry Milk Plant
(g) Ice Cream Plant
(h) General Dairy

The processes involved under each of these classifications are as follows:

(a) Receiving Station - This is a collecting station for raw milk where milk sheds are of such size that the product cannot be brought directly to the processing plants.

The milk is received in cans and the process merely involves dumping, sampling, weighing, cooling to between 35° and 40° F., and loading into tank cars or trucks for shipment to the processing plants. Remaining operations consist of washing of cans, vats, cooling equipment, and floors.

(b) Bottling Works - Raw milk and cream is received in cans, tank cars, or tank trucks. Process operations consist of can dumping, sampling, weighing, clarification, preheating, filtration, pasteurizing, cooling, and bottling of milk and cream. Other operations include the washing of bottles; cases; cans; vats; apparatus for clarifying, heating, pasteurizing and cooling; and floors.

(c) Cheese Factory - The raw material is whole milk, and, in some cases, cream or skim milk. The intake milk is weighed, preheated, pasteurized, cooled, and filtered.

Cheese may be classified according to the kind of milk used, the process of making, and the seasoning or ripening. Skim milk, which is either separated from the raw milk or obtained from other sources, is run into vats with whole milk and a "starter" lactic acid bacteria) is added. The amount of "starter" used runs from 1 to 3 percent of the milk weight. The mixture is llowed to set and ripen at controlled temperatures until proper cidity has developed. Rennet, a substance obtained from the tomach of calves, is then added. This precipitates the casein rom the whey, the process taking from 10 to 15 minutes at 86°F. he curd is cut by knives, piled and turned periodically cheddared) to release entrained whey. After draining and, in ome cases, washing, the curd is put in press forms and placed nder controlled temperature and humidity conditions for ripening nd flavoring. In this process, the casein is peptonized and hanged into forms that are digestible, and the characteristic flavors are produced. For processed cheese the ripened product is ground, melted, pasteurized to stop ripening, and packed while hot.

(d) Creamery - Whole milk, sour cream, and sweet cream are processed into butter and other products.

The whole milk is separated for its cream content and the by-product skim milk is disposed of variously to condensing or dry milk plants. The cream is then "ripened" or soured and the butter churned from the sour cream. On the farm this "ripening" is generally accomplished by allowing the cream to sour spontaneously. In the larger dairies, however, the cream collected from various sources is preheated, filtered, pasteurized, and cooled, and then ripened by means of a "starter". The chances of getting a poor flavor in a large creamery batch are great, hence the "starters" employed are carefully guarded by competent bacteriologists. After ripening the cream is churned. This is merely a mechanical means of demulsifying the fat, the minute globules cohering to form larger and larger globules until a solid mass is obtained. The butter is next kneaded and washed, either in or out of the churn, to remove any remaining buttermilk,and is packed. The buttermilk may be condensed or dried and sold. Its chief use is for stock feeding,with some utilization for baking.

(e) Condensery - Whole milk, skim milk, or other dairy products are condensed to produce unsweetened evaporated milk or sweetened condensed milk.

For the production of unsweetened evaporated milk the whole milk is first preheated in a hot well by direct steam in order to inactivate enzymes causing physical and chemical changes and to get desirable physical properties of the final product. The heated milk is then evaporated either by batch evaporation, in which the evaporator is loaded and heat maintained until the charge reaches the desired specific gravity, or by the continuous method, in which the flow through the evaporator is carefully regulated to produce a continuous discharge of evaporated milk having the desired specific gravity.

The evaporator consists of a closed tank heated by coils. The source of heat is generally exhaust steam or hot water from the vacuum pumps and other equipment. A vacuum sufficient to cause the milk to boil at about 135° F. is maintained. Vapors are taken off through a top outlet and condensed by a water spray. In some cases live steam is blown through the milk after evaporation in order to produce the desired consistency, the temperature reaching about 210° F. for a short time.

After evaporation, the milk is homogenized; i.e., forced at high pressures through a closely set valve to break up fat globules and produce a fine suspension. Cans are filled and sealed by machine, after which they are either treated in a continuous sterilizer or a batch sterilizer. In the latter the filled cans are loaded into metal baskets on a wheel rack which revolves in a horizontal closed tank containing enough water to immerse the lower baskets. The steam is turned on and the cans are subjected to contact with the steam and hot water by rotation of the rack. The heat is maintained at about 235° F. for 20 to 30 minutes. The cans are cooled by circulating cooling water, after which samples are incubated at 80° F. for about 3 weeks to disclose any incomplete or improper sterilizing as shown by swelling of cans.

Sweetened condensed milk is produced in the same manner except that sugar is added in the evaporators, a higher temperature is maintained in order to dissolve the sugar, the milk is evaporated to a greater density and the product is not sterilized after canning, the sugar acting as a preservative. Other condensery products include evaporated or condensed skim milk, whey, and buttermilk.

Remaining operations consist of washing of cans, equipment, and floors.

(f) Dry Milk Plant - Powdered milk is produced from whole, skim, or buttermilk by one of the following methods:

(1) Atmospheric Drum Method - The milk is preheated or condensed as in the production of evaporated milk and then fed through perforated pipes as a thin film to two steam heated drums revolving toward each other. The regulated clearance between drums assures an evenly spread thin coating which dries quickly. The film is scraped off by a fixed knife and barreled for market.

(2) Vacuum Drum Method - A single drum revolves in a vacuum chamber. The preheated or precondensed milk is discharged to a delivery tray feeding the revolving drum. The drum picks up a thin film which quickly dries and is scraped off by a knife. This method allows drying at reduced temperatures.

(3) Spray Method - The preheated or precondensed milk is atomized and sprayed into a current of heated air passing through the drying chamber, the solids falling to the bottom. Any solids carried off by the air are removed by passing the

exhaust through a heavy unatomized spray of incoming milk.

Cleanup washes and rinses of equipment, floors, and receiving room complete the operations.

(g) Ice Cream Plant - Ice cream and ice cream mixes are made by combining various forms of milk with sugar, gelatine, eggs, flavoring, and other ingredients. In general, the process consists of mixing the pasteurized milk and cream with the other ingredients, pasteurizing, homogenizing, cooling, measuring, and freezing. Nuts, fruits, and other ingredients which cannot be homogenized are added at the freezer.

Remaining operations are the washing of freezing and receiver units, cans, floors, pasteurizer, and other equipment.

(h) General Dairy - Manufactures various combinations of some or all of the above products.

Raw Materials and Products

Some relationships between raw materials, products and employees are given in Tables Mk-2 and Mk-3. They are intended to show general relationships only, since considerable variability of product yield exists due to differences in the raw material, the processing methods, quality of the final product, and the use for which it is intended.

Table Mk-2 Ratio of Products to Raw Material

Process	Raw Material	Products Lbs. per lb. raw material
Separation	Whole milk (4% ± B.F.)	Cream - 0.12 (30% to 40% B.F.) Skim - 0.88
Cheese making	Whole milk	Cheese - 0.10 By-product cream - 0.02 Whey - 0.88
do	Skim milk	Cottage Cheese - 0.16 Whey - 0.84
Butter churning	Cream (30% B.F.)	Butter - 0.37 Buttermilk - 0.63
do	Butterfat	Butter - 1.25

Table Mk-3 Ratio of Employees to Raw Milk Intake

Type of Plant	Number of employees per 10,000 lbs. milk intake daily
Receiving Station	1.5
Bottling Works	8.9
Cheese Factory	3.8
Creamery	1.63
Condensery	4.7
Dry Milk Plant	3.9
General Dairy	
General Average	10.9
Intake less than 10,000#/day	16.7
Intake over 10,000#/day	9.9

Sources and Quantity of Waste

There are several sources of wastes in the dairy industry, the chief of which are as follows:

(a) Whole milk left in cans and equipment - In can dumping, particularly where done at a high rate, considerable milk is left in the can and this may go to the sewer through drippings and can washes unless precautions are taken. The loss may vary from 0.1 to as high as 6 percent, averaging about 1 percent. Aside from producing no revenue, it may become an expense through cost of treatment. A small amount of milk may also remain in various piping and continuous flow equipment at the end of a run.

(b) Process operations - These may include whey, buttermilk, skim milk, sour cream, and butter and cheese washes. They are not ordinarily discharged as waste and should not be under any circumstances.

(c) Cooling waters - The source of this waste is from ammonia and vacuum pan condensers, sterilizers, and pasteurized milk or cream coolers.

(d) Domestic waste - Originates in the lavatories, locker rooms, and laundries of the milk plants.

The quantity of wastes discharged from industrial plants processing any particular material will vary widely, depending mainly upon the availability of water and management of water using operations within the plant. This is particularly true of milk products plants where rinse and wash waters of continuous flow operations may not necessarily be proportional to production; where cooling and condensing waters may or may not be recirculated in regenerative equipment; and where by-products such as excess skim milk, whey, and buttermilk may be discharged, contrary to approved methods, to the sewers.

Some average volumes of wastes are given in Table Mk-4. By-products, such as skim milk, buttermilk, or whey, and cooling waters are not included. These figures are based mainly on data from plants having no waste treatment facilities. Where such facilities do exist the volumes will tend to be less since a reduction in quantity of wastes will result in a consequent reduction of treatment costs.

Table Mk-4 Ratio of Waste Volume to Raw Milk Intake

Type of Plant	Gals. waste per 1,000 pounds milk intake daily
Receiving Station	175
Bottling Works	250
Cheese Factory	200
Creamery	110
Condensery	150*
Condensery-vacuum pan water	1,500**
Dry Milk Plant	150
General Dairy	340

* Exclusive of vacuum pan water.
** In terms of 1,000 lbs. milk condensed daily.

Character of Wastes

The wastes consist, for the most part, of various dilutions of whole milk, skim milk, buttermilk, and whey from accidental or intentional spills; drippings allowed to waste by inefficient processing equipment, methods, or operation; washes containing alkali or other chemicals used to remove milk, milk products, and partially caramelized material from cans, bottles, tanks, vats, utensils, pipes, pumps, hot wells, pans, coils, churns, and floors; and process washes of butter, cheese, casein, and other products.

Table Mk-5, taken from studies by Eldridge, shows the character of each of the principal constituents to be found in various combinations and dilutions in milk plant wastes.

Table Mk-5 Average Analyses of Milk and By-Products

Determination	Constituents in p.p.m.			
	Whole Milk	Skim Milk	Buttermilk	Whey
Total solids	125,000	82,300	77,500	72,000
Organic solids	117,000	74,500	68,800	64,000
Fat	36,000	1,000	5,000	4,000
Ash	8,000	7,800	8,700	8,000
Milk sugar	45,000	46,000	43,000	44,000
Protein (casein)	38,000	39,000	36,000	8,000
5-day B.O.D.	102,500	73,000	64,000	32,000
Oxygen consumed	36,750	32,200	28,600	25,900

The character of the specific wastes is as follows:

(a) Receiving room can dumping - Whole milk wastes are produced through the incomplete recovery of milk from dumped cans. The importance of excluding this from the stream is evident from an inspection of the organic solids and B.O.D. shown in Table Mk-5. Based on an average loss of 1 percent of the milk intake, the effect of discharging milk from incomplete can dumping alone amounts to an equivalent of 6 persons per 1,000 pounds of milk received on an equivalent sewered population B.O.D. basis.

(b) Process operations

(1) Receiving station - Ordinarily no processing, other than cooling, is done. Wastes are discussed under (a) and (c) of this section.

(2) Bottling plant - Processing consists of heating, pasteurizing, cooling and bottling. No by-products are produced. Wastes are discussed under (a) and (c) of this section.

(3) Cheese factory - Whey is produced from the addition of rennet, cheddaring, and curd cooking. Cheese washes also have the characteristics of a dilute whey. Fish do not survive in some whey and water mixtures, dilutions of the order of 1 to 25, have been found to cause death in a few hours.

(4) Creamery - Butter washes containing buttermilk are commonly discharged. Accidental or intentional discharge of buttermilk creates an exceedingly strong waste as shown by the analyses in Table Mk-5.

(5) Condensery - The vapors drawn off the milk in the evaporator are condensed by a cold water spray resulting in a large volume of condensed vapor and cooling (pan) water. The 5-day B.O.D. of this mixture varies widely, generally running between 50 and 200 p.p.m. Cooling water used to cool the sterilized canned evaporated milk may at times become highly polluted with milk from improperly closed cans. Spills of spoiled milk from these constitute a potential source of strong wastes.

(6) Dry milk plant - Process wastes are, in general, similar to those from a condensery. However, they may cause added difficulties, depending upon the practice in handling the milk dust on equipment and floors.

(7) General dairy - Process wastes consist of combinations of some or all of the above.

(c) Rinses and washes - These are made up of dilutions of whole milk, skim milk, buttermilk, and whey from the rinsing, washing, and sterilizing of containers and equipment, as well as fresh and caramelized milk products and the alkaline washing powders used. The floor washes contain dilutions of these and, in addition, dirt, sawdust, broken glass, and other similar refuse. The dry milk plant floor washes may be particularly strong in milk solids where milk dust on equipment and floors is allowed to accumulate. Table Mk-6 presents typical analyses of wastes, including floor washes, from different types of plants.

Table Mk-6 Typical Analytical Results of Milk Plant Wastes

Type of Plant	Solids				Oxygen		pH
	Total	Vol.	Susp.	Vol. Susp.	Cons.	5-day BOD	
Rec. Station	1141	844	-	-	312	509	-
Cheese Factory	1528	917	751	703	-	998	7.0
Creamery	2422	1141	664	483	-	1246	7.7
Condensery	2793	1233	754	582	-	1291	7.8
Dry Milk Plant	2407	540	-	-	283	485	-
General Dairy	1483	888	536	404	-	567	5.3

Table Mk-7 gives the average milk solids content of wastes from various types of plants. Because of the wide variation in individual cases these figures should not be relied upon in the design of waste treatment facilities. They are given here to serve as a guide in cutting down losses within the processes where individual cases vary widely from the average. Waste volumes and B.O.D. values are also shown for comparative purposes. The figures are representative of the ordinary wash wastes and process losses, not including by-product skim milk, buttermilk, or whey except the amounts included in cheese and butter washes.

Table Mk-7 Volume and Strength of Milk Product Wastes

Type of Plant	Total Milk Solids ppm	5-Day B.O.D. ppm.	Ratio B.O.D. to Milk Solids	Volume Gals. per 1000 lbs. Milk Rec'd.
Rec. Station	700	509	0.73	175
Bottling Works	600	-	-	250
Cheese Factory	-	998	-	200
Creamery	1500	1246	0.83	110
Condensery	1200	1291	1.08	150*
Dry Milk Plant	1200	485	0.40	150
General Dairy	-	567	-	340

* Exclusive of vacuum pan water; pan waters have a B.O.D. of 50 p.p.m. or less and a volume of 1000 to 1500 gallons per 1000 pounds milk received.

Typical sewered population equivalents, in terms of B.O.D., from various sources are given in Table Mk-8. These values represent wash wastes and process losses but do not include by-product discharges.

Table Mk-8 Typical Sewered Population Equivalents -B.O.D.

Type of Plant	Persons per 1000 lbs. milk intake		
	A	B	C
Rec. Station	2.8	4.8	4.4
Bottling Works	4.7	5.6	6.2
Cheese Factory	16.1	-	10
Creamery	-	5.0	6.8
Condensery	4.8	6.0	7.2
Dry Milk Plant	-	6.0	3.6
General Dairy	-	-	9.6
Creamery	- 9.4 persons per 100 lbs. butter produced.		

The variation in strengths of wastes from the various types of milk plants is within the range that can be expected in plants of the same industry. Receiving stations, as might be expected from the fewness of operations, show the lowest sewered population equivalents while cheese plants, where small amounts of whey are often discharged in cheese washing operations, show the highest values.

From the analyses given in Table Mk-6 the ratio of 5-day B.O.D. to suspended solids was found to average 1.52. Applying this factor to the B.O.D. sewered population equivalents and a correction for per capita daily oxygen requirements, based on 0.167 pound 5-day B.O.D. and 0.2 pound suspended solids per person, respectively, gives the population equivalent on a suspended solids basis.

By a study and weighing of results from various sources, average population equivalent figures are concluded to be as shown in Table Mk-9. Data on suspended solids in the by-products are not available.

Table Mk-9 Average Sewered Population Equivalents - B.O.D. and Suspended Solids

Type of Plant	No. of Persons		Unit
	B.O.D.	Susp.Sol.	
Rec.Station	4	2	1000 lbs. milk Rec'd.
Bottling Works	6	3	do
Cheese Factory	16	9	do
Creamery	6	3	do
Condensery	7	4	do
Dry Milk Plant	6	3	do
General Dairy	10	5	do
By-Products*	160	-	100 gals. whey
	320	-	100 gals. buttermilk
	365	-	100 gals. skim milk

* Additional when discharged to sewer.

Pollution Effects

Since milk wastes are organic in nature, the polluting effects are almost entirely due to the oxygen demand which they impose on the receiving stream. Fresh wastes may be acid or alkaline. Where receiving waters cannot provide sufficient oxygen for aerobic decomposition the lactose is converted to lactic acid and the wastes become sufficiently acid to precipitate the casein. The heavy black sludge deposits and strong pigpen odors caused by the putrefying casein characterize milk waste pollutions.

Remedial Measures

The subject of milk plant wastes, with methods of recovery and treatment, has been extensively studied for years by state and federal health agencies, experiment stations, and individuals. Many of these developments have been incorporated in full size treatment works for which results under actual operating conditions are available. For the purposes of this guide such results have been used,where available, to demonstrate the various types of treatment. Remedial measures may be classified as by-product recovery, or processing and waste treatment.

By-Product Recovery

By-product recovery is profitable to the milk plant operator since it permits a defrayal of part or all of the expense chargeable to waste treatment. There are very few milk plants operating today in which it is not possible to effect an apprec reduction in milk losses by more careful operation, by the installation of more modern equipment, or both.

Drip savers - These may be used ahead of the can washers. The equipment is relatively inexpensive and very effective. Another major loss in the milk plant occurs in draining and washing equipment operations. Air jets have been used effectively for blowing out the lines of coolers and piping. Small amounts of water for initial rinsing of this equipment washes out the milk not blown out by the air.

That these devices are worthwhile has been proven by actual installations. At a bottling plant in Pennsylvania catch sample of these wastes during peak operation showed a B.C.D. of about 1,000 p.p.m. before the changes were made. An analysis of a composite sample taken after the changes were made showed a B.O. of about 150 p.p.m., far less than is normally found in a plant of this type. Tests of the wastes made with and without the equipment rinsings separated gave the results shown in Table Mk-

Table Mk-10 Summary of Drip Saver Performance, Pennsylvania.

Determination	Rinsings Left in	Rinsings Out	Percent Reductio
	Results in p.p.m.		
Total Solids	869	585	36
Volatile Solids	291	90	69
Suspended Solids	372	188	49.5
Protein	78	33.5	57
Fat	144	34	76
5-day B.O.D.	1,000	150	85

Considering that whole milk has a B.O.D. of 102,500 p.p.m., the importance of preventing any of it from reaching the stream is evident. The milk recovered in this manner is generally used for stock feed, most states forbidding its use for human consumption.

Skim milk - This is not ordinarily discharged as a waste nd should not be disposed of in this manner under any circumtances. Where processing is not practiced, it may be returned o the farmer for use as stock feed. However, it may be conerted into several useful by-products, the chief of which are s follows:

(a) Chocolate skim-milk beverage - Produced by flavoring kim milk with chocolate and sugar.

(b) Skim milk powder - Produced by hot roll or spray drying. ts chief uses are in baby foods, ice cream manufacturing, bread aking, and animal foods.

(c) Casein - Precipitated from the skim milk by adding ilute acids or rennet. The casein is separated, washed, and ried. It has a wide variety of commercial uses, principally in he paper industry as sizing for high grade papers, casein glue, lastics, filler or binder in certain foods, and as a constituent f paints.

(d) Albumin - Obtained from the casein recovery whey through oagulation by heating to 70°C. It is not acted upon by rennet r acids at ordinary temperatures. The chief use is as a constituent for poultry feed.

(e) Lactose - Commonly known as milk sugar. It is peculiar o milk and is found nowhere else in nature. Commercially it s obtained as hard rhombic crystals from the evaporation of the asein and albumin recovery whey. The lactose is readily converted o lactic acid by bacterial fermentation. Lactose and its by-products are used mainly in pharmaceutical preparations, baby foods, ice cream sherbets, preserving pickles, olive packing, printing colored fabrics, and deliming of hides in tanning.

Whey - This by-product of cheese manufacture, is another aterial which should not and ordinarily is not discharged as a aste. Small amounts of it are discharged with cheese washes. he presence of even small amounts may upset any of the milk lant waste treatment methods in use today. Several processes hose function is to reduce the strength of the whey or eliminate it altogether have been attempted and a few have been found racticable.

The two most feasible methods of disposal at present appear t be drying and stock feeding. In the drying method, as practiced a one plant, 100 gallons of fresh whey are mixed with about 80 punds of corn flour, bran, middlings, or a mixture of these. The toroughly mixed and thickened whey is pumped upon slowly revolvig steam heated rolls from which it is scraped, carried by a conveyor to a screen, and the screenings bagged or barrelled. The yield is about 124 pounds of dried feed per 100 gallons of whey. This product is used chiefly as a poultry feed. Another practice is to run the whey through a separator to recover the cream used in the manufacture of whey butter. The residual whey contains albumin and lactose, which are both recoverable, as discussed under skim milk processing.

Where recovery by-processing is not practiced, the whey may be sold or given to farmers as stock feed or it may be disposed of by irrigation on isolated farm land.

Buttermilk - The methods for disposing of excess buttermilk and butter wash waters are similar to those for the disposal of whey. The buttermilk may be evaporated to a semi-solid, in which form there is a demand for stock feeding, or it may be converted into a poultry feed by hot roll drying. When no processing is done, disposal may be to farms as stock feed.

Treatment

Where by-product recovery is not practiced or is insufficient, treatment is necessary. In the following paragraphs are discussed important features of the more common methods as well as typical installations.

(a) Dilution - The process consists of discharging the wastes in such a manner as to enable their being cared for either by a stream or municipal treatment plant. This is done by using a holding tank of such size and outlet facilities that the raw wastes may be discharged over a longer period of the day than that in which produced. Provision should be made for aerating or circulating the tank contents or chlorinating the influent in order to keep the wastes fresh and delay decomposition during the holding period.

(b) Irrigation - This method is applicable to small plants located on farms or in outlying districts where the waste may be spread over land under constant cultivation or on isolated waste land. A sandy soil is required. Odors may be controlled by the use of sodium hypochlorite or chloride of lime. The method is generally used only during the summer months when stream flows are low.

(c) Imhoff Tanks - This type of treatment is not considered to be of much value for milk plant wastes. Upon entering the tank the milk or cream begins to sour and the suspended matter formed, having a low specific gravity, rises to the surface and forms a scum in the flow section. The solids adsorbed by this scum cause the clogging of filter units. Also, the acidity developing as a result of storage inhibits bacterial activity. The Imhoff tank soon becomes, in reality, a septic tank.

(d) Septic Tanks - Opinion is divided on the value of septic tanks when applied to milk plant waste. Eldridge states that the septic process cannot be successfully applied to milk waste, since products are formed by septic fermentation of milk solids that are more detrimental to the stream than the fresh solids. Trebler is of the opinion that when strong wastes are removed, the proportion of cleaning alkalis to milk sugar becomes larger and gives the septic tank an opportunity to work, especially if the pounds B.O.D. load per unit volume tank capacity is kept within the limits for domestic waste and if the tank is seeded properly initially. Under these conditions it is reported that good reduction in fat and suspended matter and from 30 to 50 percent reduction in B.O.D. may be expected.

A large number of septic tanks are still in use, either alone or as pretreatment for removal of the gross solids before application of wastes to filters. Table Mk-11 summarizes the performance of the septic tank treatment plant at a milk receiving station in Moravia, N.Y.

Table Mk-11 Summary of Septic Tank Performance, New York

Determination	Raw Waste p.p.m.	Septic Tank Effluent-p.p.m.	Reduction percent
Total solids	1,141	727	36
Volatile solids	844	337	60
Organic N.	27.18	4.68	83
Free NH_3	1.5	20.0	1,200*
Oxygen consumed	312	65.9	78
Chlorine demand	14.4	24.9	73*
1-day B.O.D.	48.3	114	136*
5-day B.O.D.	509	395	22

* Increase.

(e) Anaerobic stabilizaton - Buswell found, from experimentation with whey and buttermilk, that by feeding these raw untreated materials to an anaerobic digestion tank (or two in series) at rates of from one twentieth to one thirtieth of the tank volume per day about 95 percent reduction in pollutional strength could be obtained. He reports that from 8.3 to 12.4 cubic feet of gas having a B.T.U. content of 550 can be recovered at a moderate cost per pound (dry weight) of milk solids. The tank effluent was neither sour (pH 7.0 to 7.5 and volatile acids as acetic, amounted to only 500 to 1,850 p.p.m.) nor highly putrescible, and contained but little settleable solids. The required tank size (or sizes if operated in two stages) would be 5.7 cubic feet per pound of waste milk solids per day. It was suggested that in most cases the tank effluents be further treated by application to slag, stone, lath or sand filters; by discharge to city sewers and subsequent treatment; or to streams having sufficient flow. Relative initial costs of treatment plants per pound of milk solids applied per day were given as follows:

Fermentation tank alone.	$2.86
Fermentation tank plus trickling filters .	8.70
" " " sand " .	17.46
as compared with:	
Trickling filters alone.	116.80
Sand " "	292.00

Trebler commenting on this method states that with the present great excess of whey solids and the low prices paid, such a process might be economical and that a cheese factory could probably make enough gas for its fuel needs. The process is not known to be in commercial use in the milk industry.

(f) Biological filtration - The use of filters has received very extensive study and has been found to be the most generally applicable treatment method for milk wastes.

Eldridge found that reductions of 65 to 70 percent of the B.O.D. were possible in the operation of a standard filter (operated at about 1 m.g.a.d. without recirculation) on raw waste having a 5-day B.O.D. of between 500 and 800 p.p.m. In general, strong wastes cannot be applied with success. Kimberly cites a tentative limit of 800 p.p.m. 5-day B.O.D. for successful operation at a rate of 1 m.g.a.d. Wastes of greater strength may be diluted with cooling or pan waters before application to the filter. On the basis of milk solids applied, Agar reports that satisfactory operation generally will result if the rate of application is not over 1 pound of milk solids per 80 cubic feet of filter volume per day for filters 6 to 10 feet deep. Levine found application of wastes in small amounts at frequent interval to be more effective than large amounts applied at longer interva The revolving distributor possesses advantages over the fixed nozzle and tipping trough distributors in this respect.

The removal of gross suspended solids before filtration will help prevent filter clogging. Secondary settling is desirable to eliminate filter sloughings from the final effluent. Ventilation of filters is also desirable and has been accomplished by building filters above ground with wire net side walls, or by using cement block with open joints.

The type of filters which have received the most extensive study are as follows:

(1) Lath Trickling Filter - as described by Frank and Rhynus, has been suggested as a treatment method for small plants. It can be cheaply constructed and maintained with readily available materials. The filter is dosed by a tipping trough. Such units should be housed to prevent freezing and help control odor nuisance. The use of a holding tank to smooth out application of waste and spread the discharge over several hours each day is advisable.

(2) Sand Filters - Hommon, as a result of sand filter studies (1915-17), recommended underdrained sand filters consisting of 1 foot coarse stone overlain by 4 feet of sand dosed at a rate of 50,000 g.a.d. A septic tank designed for 48 hour detention with a 30 percent additional volume for sludge and scum accumulations was to be provided for primary treatment. Walker also found sand filters applicable and successful at rates of 75,000 to 100,000 g.a.d.

It is likely, however, that with the development of the higher rates on the coarse media, the sand filter is too limited by cost and space requirements to offer any competition.

(3) Coarse Media Filters - Slag and stone are commonly used for trickling filter materials. Levine studied the effects of various filter media experimentally. The removals obtained are shown in Table Mk-12. The experiments were performed on raw skim milk wastes with B.O.D.'s varying from 200 to 1,600 p.p.m. and were applied at a rate of 550,000 g.a.d. The experimental filters were 2 ft. square and 6 ft. deep.

The cinders, while giving high efficiencies, clogged frequently and washing was necessary after 5 months operation. Corncobs gave good removals although no nitrates were formed. The bed shrank 35 percent in depth and efficiency decreased sharply at the end of a 9-months test. The 3-inch spiral ring packing was considered too large for outstanding results. It was thought that excellent results would be obtained on smaller rings.

Perforated tin cans have also been tried experimentally. With three of these filters, each 2 feet in diameter by 6 feet deep, in series and dosed at a rate of 5 m.g.a.d., a removal of 1 pound of B.O.D. per 8 cubic feet of filter volume was accomplished without dilution or recirculation.

A filter volume of 80 cubic feet per pound of milk solids applied for filters 6 to 10 feet deep is commonly referred to in design. In all cases the removal of the larger suspended solids prior to application on the filter and final settling to collect filter sloughings, is desirable.

Table Mk-12 B.O.D. Removals on Various Filtering Media

Filter Medium	B. O. D.			pH
	Raw Waste p.p.m.	Effluent p.p.m.	Removal percent	Effluent (raw pH-6.7)
Lath (sectional)*	565	28.9	94.9	7.8
Cinder "	565	13.6	97.6	7.7
Cinder "	508	20.1	96.0	7.8
Cinder (solid)	508	10.6	97.9	7.8
Gravel	513	15.5	97.0	7.8
Spiral rings	513	105.0	79.5	7.7
Corncobs	761	63.0	91.1	8.1
Broken tile	761	31.5	95.6	8.2
Cinder	1000	8	99.2	8.2
Quartzite	1000	144	85.8	8.2

* Six 1 foot layers of lath (or cinders) each separated from the succeeding layer by a 4 inch air space.

(4) High Rate Recirculating Filters - Recent studies on high rate application and recirculation of a mixture of raw waste and a portion of the filter effluent has demonstrated the possibility of both producing higher removal efficiencies and reducing the size of filter required. The strength of the effluent produced depends on the initial strength of the raw waste and the number of times circulated. This makes possible the treatment of strong raw wastes without dilution and, by sufficient recirculation, the production of highly purified effluents.

Halvorson obtained experimental reductions of 85 to 95 percent operating on wastes having B.O.D.'s of 2,500 to 3,50 p.p.m. The filter material used was specially fabricated tile laid vertically to form a series of vertical conduits 1 inch in diameter. This was reported to minimize channeling and ponding, and to give a larger surface area per cubic foot than average filter stone. The filter was ventilated by use of a fan. For very strong wastes, it was found desirable to pretreat them in a septic tank by allowing souring, with resultant precipitation of casein, to take place. The tank effluent (pH=4.5) was mixed with a portion of the filter effluent (pH over 7.0) and applied by means of a revolving inverted cone distributor above the center of a circular bed.

Eldridge investigated recirculating filters both on a continuous flow and a fill-and-draw basis. In the continuous recirculation studies it was found that the number of times the waste was recirculated had a greater effect on the filter efficiency than the loading and that with a given number of recirculating cycles the effluent obtained was about the same regardless of the raw strengths applied. A series of tests were run on a filter 6 feet deep and 20 square feet in area. The filtering material used was 1 foot of 3½-inch stone overlain by 5 feet of graded 1½-inch to 2½-inch gravel. Provision was made for natural ventilation. The waste was pumped from a storage tank to an orifice box from which a measured quantity flowed to a pump sump for mixing with part of the settled filter effluent. This was applied to the filter continuously by means of a rotary distributor. A quantity of settled effluent equal to the raw waste influent was discharged and the remainder returned for recirculation. The results obtained from a series of runs at each of 3 rates of raw waste application and recirculation (in this case these were interdependent in that the total application; i.e. raw waste plus return effluent, was equal to 20 m.g.a.d. for each run) on raw wastes ranging from 331 to 1,330 p.p.m., 5-day B.O.D. gave removals of 21.0 to 92.8 percent. The average results obtained from each of the three series are shown in Table Mk-13.

Table Mk-13 Performance of Continuous High Rate Trickling Filter

Filtration Rate m.g.a.d.		Times Recirculated	5-Day B.O.D.			B.O.D. Loading	
Raw	Applied		Raw p.p.m.	Filtered p.p.m.	Reduction Percent	Lbs. per Cubic Feet	Cu. Ft. per Lb.
4.9	20.0	4.0	508	267	47.4	79.6	14.4
3.4	20.0	6.0	417	146	65.0	44.3	31.9
2.4	20.0	8.3	714	118	83.5	52.6	21.5

The saving in filter size is apparent from the above, an average of 83.5 percent B.O.D. removal being obtained with a filter volume of 21.5 cu. feet per pound of B.O.D. applied. Filters of this type give reported removals equivalent to those of standard trickling filters while using a filter volume of 1/2 to 1/3 that of the standard filter. The efficiency of existing standard filters may be increased by a change-over to provide for recirculation.

Studies were also conducted by Eldridge on the application of this principle on a fill-and-draw plant which might satisfy the needs of a small dairy. Tests were made on a stone filter of the same depth and filling materials as used for continuous recirculation. Raw wastes ranging from 237 to 2,100 p.p.m. B.O.D. were recirculated from 4 to 36 times. Reductions in B.O.D. ranged from 47.4 percent on raw wastes averaging 508 p.p.m. B.O.D. recirculated 4 times to 98.3 percent B.O.D. reduction on raw wastes averaging 1,780 p.p.m. B.O.D. recirculated 33 times.

The plant suggested as a result of these tests consists of a hopper bottom tank of capacity equal to the volume of waste produced during one day, a small pump, rotary distributor, and a filter 6 to 7 feet deep and of such area as to provide 1 square foot of surface area per 30 to 35 gallons waste produced daily. Filtering material is 2 to 3½ inch stone. Rate of application should be about 20 to 25 gallons per square foot per hour. In operation, the tank would be emptied each morning and filled during the day, the waste being applied to the filter continuously. Sludge is withdrawn from the hopper bottom to a sludge pit before drawing off the treated waste.

Studies were made at a receiving station and milk powder plant in Elba, N.Y. The whole milk intake was 69,300 pounds per day and wastes amounted to 58,500 gallons per day. The trickling filter is 8 feet deep and operates 18 hours per day at a rate of 2.8 m.g.a.d. or 140 cubic feet per pound of milk solids. Results of analyses, obtained by averaging a series of catch and composite samples for a two-day period, after two months' operation, are presented in Table Mk-14.

Hatch and Bass conducted an investigation of the waste disposal facilities of the Pet Milk Company at Coldwater, Ohio. The plant is modern in every respect and is equipped to handle a whole milk intake of 300,000 pounds per day. The principal product is canned evaporated milk, although some ice cream mix is manufactured and equipment is available for producing skim milk powder.

Table Mk-14 Trickling Filter Performance, Milk Receiving Station and Powder Plant, New York

Determination	Raw Waste p.p.m.	Filter Effluent p.p.m.	Reduction percent
Total solids	2407	2094	13
Volatile solids	540	299	45
Total N	22.4	8.0	64
Oxygen consumed	283	103	64
Chlorine demand	4.8	25.8	538 *
1-day B.O.D.	67.5	23.6	65
5-day B.O.D.	485	56.3	89

* Increase. Probably due to breakdown of sulfates.

Industrial wastes, averaging 30,800 gallons per day during the tests, are made up of floor and equipment wash water, wastage from the condensing water recirculation system, and sludge from the lime-soda softening of the boiler water. Treatment facilities consist of a primary settling tank, an excess raw waste storage basin, settled waste pumps, trickling filter, and secondary settling tank. Raw waste, after preliminary settling, is diluted with pan water, plant effluent, or a combination of both before being applied to the trickling filter. The ratio of applied waste to raw waste is about 12 to 1.

Operating results, obtained from the average of a 30-day series of samples composited in proportion to the flow, are presented in Table Mk-15.

Table Mk-15 Trickling Filter Performance, Condensed Milk Plant, Ohio.

	Raw Waste	Filter Influent	Filter Effluent	Final Effluent
	Results (except pH) in p.p.m.			
Total Solids	2793	1687	1628	1628
Volatile Solids	1233	346	296	276
Suspended Solids	754	51.1	17	14
Volatile Suspended Sol.	582	41.6	13	11
5-Day B.O.D.	1291	56.5	8.3	6.4
pH	7.8	7.2	8.0	8.0

Ruf and Warrick studied the characteristics of a condensed milk waste treatment plant at Chilton, Wisconsin. The average milk intake during the study was about 163,000 pounds daily, the maximum capacity of the dairy being 200,000 pounds per day. Cooling and condensing waters from the pan are discharged directly to a nearby creek, all other wastes passing through the treatment plant. Facilities include a hopper bottom storage tank, rotary distributor, an uncovered circular filter, and a hopper bottom secondary settling tank. The filter is built entirely above ground. Its walls are made of pipe uprights embedded in a concrete curb and supporting 3/4" chicken wire strengthened by fence wire.

Average results from six complete tests of operation are given in Table Mk-16. Winter samples taken when air temperature was about 46°F. and the influent and effluent temperatures 57° and 41°F., respectively, showed a 5-day B.O.D. reduction for a raw waste of 1,490 p.p.m. of 82 percent. Little difficulty was encountered with this open filter in two winters of operation.

Table Mk-16 Trickling Filter Performance, Condensed Milk Plant, Wisconsin

Item	Unit	Filter Influent	Filter Effluent	Final Effluent	Percentage Removals	
					Filter	Final
Dosage rate	m.g.a.d.	0.75	-	-		
" "	*	96	-	-		
" cycle-on	Min.	8	-	-		
" " -off	"	7				
5-day B.O.D.	p.p.m.	628	87	52	86	92
Oxygen cons.	"	863	218	175	75	80
Total organic N	"	36	16	14	55	61
Free NH_3	"	38	1.8	2.3		
Nitrite Nitrogen	"	-	1.4	1.3	-	
Nitrate "	"	-	3.0	2.7	-	
Total solids	"	2442	1859	1823	24	25
Volatile solids	"	1206	613	588	49	51
Soluble solids	"	2061	1661	1659		
Susp. solids	"	381	196	164	49	57
Vol.susp.solids	"	376	164	136	58	64
Ave. pH		7.1	8.1	8.1		
Ave. D.O.	p.p.m.	-	5.9	5.9		
Reducible sugars	"	121	0	0		
Temp.	°C.	21	17	17		

* Cubic feet of filter per pound of 5-day B.O.D. per 24 hours.

Eldridge converted a low-rate trickling filter into a high-rate recirculating filter at Perinton, Michigan. The filter had been operated for several years as a standard filter and the best removal of B.O.D. ever obtained was 60 percent. At present the wastes pass through a rough screen to a holding tank, with a capacity of about one-half the daily flow. A centrifugal pump applies this effluent through a rotary distributor at a net rate of 3.4 m.g.a.d. or a gross rate of 16 m.g.a.d., giving a ratio of applied waste to raw waste of 4.7 to 1. The filter effluent discharges through a secondary settling tank to a nearby stream. Average operating results, based on a nine-day series of composited hourly samples proportioned to the volume of wastes at the time of collection, are shown in Table Mk-17.

Table Mk-17 Performance of High Rate Recirculating Trickling Filter, Michigan

Determination	B.O.D.	Suspended Solids
Raw Waste	537 p.p.m.	484 p.p.m.
Filter Influent	106 "	140 "
Filter Effluent	44 "	91 "
Final Effluent	46 "	92 "
Overall Reduction	90.6%	77.1%

A few accounts of British installations and experiments with trickling filters are available. The report of the British Water Pollution Research Board for 1939 contains an account of experiments on the treatment of whey washings from a cheese factory by two-stage trickling filters and by activated sludge. The two-stage filters, operating at 160 Imperial gallons per cubic yard of filter medium, produced an effluent of 70 p.p.m. from whey washings of 270 p.p.m. The activated sludge process reduced the B.O.D. of the washings from 660 p.p.m. to 60 p.p.m., using a 36-hour aeration period. Scarlett describes a plant in which wastes are subjected to a one-day aerobic fermentation at 30°C., sedimentation, straining through cocoanut fiber mats, and treatment on trickling filters. B.O.D. values of 400 to 800 p.p.m. in the raw waste were reduced to 10 p.p.m. in the effluent.

(g) Activated Sludge - While this method of treatment is not new for industrial wastes in general, it has not been used extensively for milk factory wastes.

At New Bremen, Ohio, activated sludge treatment is being used on wastes from a dairy whose chief product is butter, but which also manufactures sweetened and unsweetened skim condensed milk, whole milk and skim milk powder, ice cream and ice cream mix, and semi-solid buttermilk. The averages shown in Table Mk-18 were obtained from analyses of a 29-day series of samples composited in proportion to flows. During the tests the daily intake averaged 69,133 pounds of whole milk and 21,065 pounds of sour cream while the waste flow averaged 29,700 gallons per day.

Table 18 - Performance of Activated Sludge Plant, Creamery and General Dairy, Ohio

Determination	Raw Waste	Primary Tank Effluent	Final Effluent
	Results	(except pH) in p.p.m.	
Total Solids	2,422	1,915	1,345
Volatile Solids	1,141	726	238
Suspended Solids	664	243	30.3
Vol. Susp. Solids	483	169	25.9
5-day B.O.D.	1,246	734	12.4
pH	7.7	7.5	8.1

Another plant at which treatment of dairy wastes, by the activated sludge process, has been successful is located at Somerset, Pennsylvania. The chief output is bottled milk, but cream, butter, cheese, ice cream and condensed milk are also produced. The average intake is 60,000 pounds of milk daily and the average waste flow to the treatment works is 50,000 gallons per day. Typical operating results at this plant are as follows:

	5-day B.O.D. p.p.m.	Total Solids p.p.m.	pH
Raw Waste	545	797	7.2
Final Effluent	7.4	466	7.7
Percent Reduction	98.4	41.5	-

A recent development is the "Mallory" process employing the activated sludge process followed by chemical precipitation with lime and alum. Treatment takes place in two prefabricated steel units, the first being an aerator-clarifier (or first stage) unit and the second being the chemical precipitation (or second stage) unit. The dairy produces bottled milk, ice cream, and cottage cheese. The daily milk intake varies from 8,800 to 10,600 pounds. A survey of the plant made on two successive days yielded the results shown in Table Mk-19.

Table Mk-19 Performance of Mallory Process, General Dairy

Determination	1st Day		2nd Day	
	Raw Waste	Final Effluent	Raw Waste	Final Effluent
Total Solids - p.p.m.	940	505	1,180	465
Volatile Solids "	700	110	900	110
Suspended Solids "	450	25	380	20
Vol. Susp. Solids"	420	20	380	15
5-day B.O.D.	969	6	890	5
pH	5.2	8.1	4.4	8.4
Wastes - g.p.d.	22,690	-	15,720	-

(h) Guggenheim Process - This type of treatment, essentially a combination of the chemical precipitation and activated sludge processes, has been most successfully used for cheese plant wastes. The wastes are discharged to a storage tank and kept fresh by agitation with air, then flow to the flash mixer where hydrated lime, a ferric salt, and return sludge are added. This is followed by about four hours aeration and, finally, secondary settling.

Eldridge conducted a series of studies on an experimental plant at Clare, Michigan. The wastes were typical of those from a cheese factory, consisting of can, equipment, and floor washings as well as sour washings from the cheese and vats. The cheese washings contain some whey and it was the presence of this which made treatment difficult. The conclusions drawn from these studies were as follows: The process can be successfully used for the treatment of cheese factory wastes. The wastes can include the cheese washings but very little, if any, of the whey. The upper limiting B.O.D. value is about 3,000 p.p.m. Return sludge should be about 33 percent of the waste volume. Proper diffusion of sufficient air is necessary to maintain dissolved oxygen in the aeration tank; and conditions must be carefully controlled if good removals are to be obtained. Average operating results, are given in Table Mk-20.

Table Mk-20 Operating Results of Guggenheim Process,
Cheese Plant, Michigan

Determination	Min.	Max.	Ave.
Aeration period - hrs.	4.5	4.5	4.5
Lime - p.p.m.	230	400	280
Ferric chloride - p.p.m.	25	87	56
pH	6.5	7.5	7.3
5-day B.O.D., influent - p.p.m.	1200	3400	2147
5-day B.O.D., effluent - p.p.m.	100	400	229
Total solids, influent - p.p.m.	1716	5792	2787
Total solids, effluent - p.p.m.	1210	1580	1401
Settleable solids, aeration tank- p.p.m.	50	200	105
Suspended solids, aeration tank - "	1300	3200	2150
D.O. aeration tank - p.p.m.	0	6.0	1.1

Hatch and Bass investigated the waste treatment works of a plant manufacturing American cream cheese at Glen Karn, Ohio, and employing the Guggenheim process. Operation involves the agitation of raw waste in the primary storage basin with air to keep the solids in suspension and the discharge of a constant quantity of raw waste from this tank to the flash mixing basin through an orifice box discharging at a constant head. The waste discharging through the orifice flows through a second brass plate screen with slotted openings 1/16" x 3" in size to the flash mixer. Here a milk of lime slurry, an iron salt solution, and return sludge from the final settling tank are added and mixed by air through a perforated pipe. The waste then passes to an aeration basin, having a four-hour detention period, and finally to a hopper bottom final settling tank with a two-hour detention period. The average daily flow of wastes during the tests was 15,570 gallons while the average daily intake was 25,563 pounds whole and 5,792 pounds of skim milk. Average operating results, as determined from a 30-day series of samples, composited in proportion to flow, are given in Table Mk-21.

Table Mk-21 Operating Results of Guggenheim Process, Cheese Plant, Ohio.

	Raw Waste	Plant Effluent	Percent Reduction
	Results (except pH) in p.p.m.		
Total Solids	1,246	1,027	17.5
Volatile Solids	663	353	46.7
Suspended Solids	352	120	66.0
Vol. Susp. Solids	308	88	71.5
5-day B.O.D.	755	167	78.0
pH	6.7	7.6	-

The failure of this plant to give the expected efficiency is said to be chiefly due to: insufficient training of and attention by the operator; uneven application of chemicals; difficulty in estimating the amount of returned sludge; lack of a primary settling tank to reduce the suspended solids and oxygen demand of the raw wastes; and too short a detention period in the aeration unit.

Treatment Costs

Available installation, operating, and maintenance costs for the various types of plants discussed are given in Table Mk-22. Operating and maintenance costs, in general, include labor, power, chemicals, depreciation, and interest.

Table Mk-22 Installation and Operating Costs - Milk Waste Treatment Plants

Treatment Process	Milk Intake 1000#/d.	Waste Flow g.p.d.	Installation Cost-$	Oper. & Maint. $/da.
Trickling Filter (a)	125.0	30,800	28,800	13.12
do	20.0	3,200	4,000	1.50
do	50.0	8,000	5,500	1.92
do	100.0	16,000	8,000	2.60
do	200.0	32,000	11,500	3.84
do	300.0	48,000	14,500	5.20
Activated Sludge (a)	90.2	29,700	15,000	13.86
do (a)	60.0	50,000	12,000	-
Mallory (a)	9.7	20,000	-	2.55(b)
Guggenheim (a)	31.4	15,570	5,300	4.91
do (a)	30.0	15,000	8,000	6.00

(a) Actual installation.
(b) Cost is 2.09 when chemical precipitation is not used.

Bibliography

(1) U. S. Public Health Service, unpublished data.

(2) Eldridge, E. F., Special Bulletin 272; Agr. Exp. Station, Michigan State College; June, 1936.

(3) Walker, C. L. et. al., Bulletin 425; Agr. Exp. Sta., Cornell University; November, 1923.

(4) Agar, C. C.; Sewage Works Journal, V. 10, p. 115, January, 1938.

(5) Hatch, B. F. and Bass, J. H., "A Study of Milk Waste Treatment," Bulletin, Ohio State Department of Health, May 1, 1940.

(6) Ruf, H. and Warrick, L. F.; Sewage Works Journal, V. 6, p. 580; May, 1934.

(7) Eldridge, E. F.; Waterworks and Sewerage, V. 88, p. 457, October, 1941.

(8) Mohlman, F. W.; Chicago Sanitary District; unpublished data, 1935-1938.

(9) Calvert, C. K. and Parks, E. H.; Sewage Works Journal, V. 6, p. 1159, November, 1934.

(10) Walker, C. L.; Sewage Works Journal, V. 2, p. 123, January, 1930.

(11) Hommon, H. B.; U. S. Public Health Service Bulletin 109, November, 1920.

(12) Trebler, H. A. et al.; Sewage Works Journal, V. 10, p. 868, September, 1938.

(13) Buswell, A. M., et al.; Industrial and Engineering Chemistry, V. 24, p. 1423, December, 1932.

(14) Eldridge, E. F.; Bulletin 77, Michigan Eng. Exp. Station, November, 1937.

(15) Kimberly, A. E.; Municipal Sanitation, V. 1, p. 89, February, 1930.

(16) Levine, M. et. al.; Bulletin 124, Iowa Eng. Exp. Station, December, 1935.

(17) Frank, L. C. and Rhynus, C. P.; U. S. Public Health Service Bulletin 101, December, 1919.

(18) Eldridge, E. F.; Sewage Works Engineering, V. 2, p. 599, December, 1940.

(19) British Water Pollution Research Board, Report for Year Ended June 30, 1939.

(20) Scarlett, C. A.; Analyst, V. 64, p. 252 (1939).

(21) Montagua, S. D.; Sewage Works Journal, V. 12, p. 109, January, 1940.

(22) Mallory, E. B., Waterworks and Sewerage, V. 87, p. 102, March, 1940.

(23) Eldridge, E. F.; Waterworks and Sewerage, V. 88, p. 457, October, 1941.

(24) Eldridge, E. F.; Bulletin 83, Michigan Eng. Exp. Station, November, 1938.

MILK PLANT WASTES

(Not an Actual Plant)

Plant Frank Milk Co.
State Ohio
Ref.No. A B - 213.4

City Larson
County Buckman
Main Watershed Atlantic River

Address 762 River Street
Sub-watershed Blue Creek

Informant A. B. Charles
Title General Manager
Principal Product General Dairy Products

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	168	365	18
Maximum	168	365	25

Seasonal variation Peak in June & July ; Minimum in January

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	City	500	700	None
Industrial	Well	1,800	2,500	None
Cooling	Well	15,000	20,000	None

RAW MATERIALS:-	Lbs. per day	Milk	Cream
Average		13,700	None
Maximum		23,000	None

PRODUCTS:- Bottled Milk Pasteurized 1,600 lb./day
Cream Pasteurized 1,000 lb. / day
Butter 125 lb./day
Cheese No estimate
Whey
Buttermilk No estimate
Milk powder None
Skim Cond. 165 g.p.d.
Other Some raw milk sold in bulk.

WASTES:- Quantity 16,800 g.p.d.
How estimated Water bills & pump capacity
Churn washings 100 gal. per day
Pasteurizer washings 200 gal. per day
Floor washings 1,000 g.p.d.
Sour cream To stock feeding
Buttermilk To stock feeding
Whey To stock feeding
Dryer residue None
Spills None reported
Disposal other than water carried None
Segregation of Strong Wastes None
Difficulties
Treatment None
Analyses: Number None
Date
By whom

OUTLET:- Where to Blue Creek

Description:	Size and shape	Material	Location	Elevation
1.	20" circ.	Tile	In back of plant	
2.				
3.				

Gaging possibilities Good. Could place weir in manhole at outlet sewer.
Conditions below outlet: Color Milky discoloration along bank
Turbidity
Deposits Some solids - black

SANITARY SEWAGE: Disposal Municipal Sewer
Persons tributary 25

REMARKS Can washings - 500 g.p.d. Company does local business. Some expansion contemplated in the near future.

Survey by D. E. Fleming
Date 8 - 13 - 1940

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an actual dairy)

River Mileage Index No. AB-213.4

Type of Plant General Dairy **State** Ohio

Name of Plant Frank Milk Company

Municipality Larson **Main Watershed** Atlantic River

County Buckman **Subwatershed** Blue Creek

Address 762 River Street

Source of Information A.B.Charles, General Manager

Plant Operation:-

24 hrs. per day, 7 days per week
18 Plant employees, maximum - 25

Seasonal Variation:-

Peak in June and July
Minimum in January

(Survey report continued on next page)

Survey by D.E.Fleming **Date** 8-13-40

Sewered Population Equivalent Computation:-

Factors used per 1000 pounds milk intake per day

B.O.D. 6 **Suspended solids** 3

Sewered population equivalent* based on B.O.D. 100

Sewered population equivalent* based on suspended solids Less than 50

Remarks:

Computation by: G.H.Irwin **Date** 11/21/40 **Cincinnati Office**

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
*Rounded to nearest 100

Frank Milk Co. AB-213.4

Water Supply

	Average	Maximum	Source	Treatment
Drinking	500 g.p.d.	700 g.p.d.	City	None
Industrial	1,800 "	2,500 "	Well	"
Cooling	15,000 "	20,000 "	"	"

Raw Materials - Average: 13,700# raw milk daily
Maximum: 23,000# " " " (May & June)

Products - Bottled pasteurized milk : 1,600#/day
" " cream: 1,000 "
Butter : 125 "
Condensed Milk : 165 g.p.d.

Cheese, buttermilk, and raw milk sold in bulk account for remainder of intake. No estimate of quantities.

Wastes - Total 16,800 g.p.d.

Can washings	500	g.p.d.
Churn washings	100	"
Floor washings	1000	"
Pasteurizer washings	200	"
Condenser cooling	15000	"

Buttermilk, whey, sour milk, and sour cream used for stock feed.

No spills were reported. Wastes are discharged untreated.

Outlet - 20" circular tile sewer in back of plant carries all wastes to Blue Creek. Gaging possible by placing weir in manhole between plant and river. Milky discoloration and some black deposits on bank of stream below outlet.

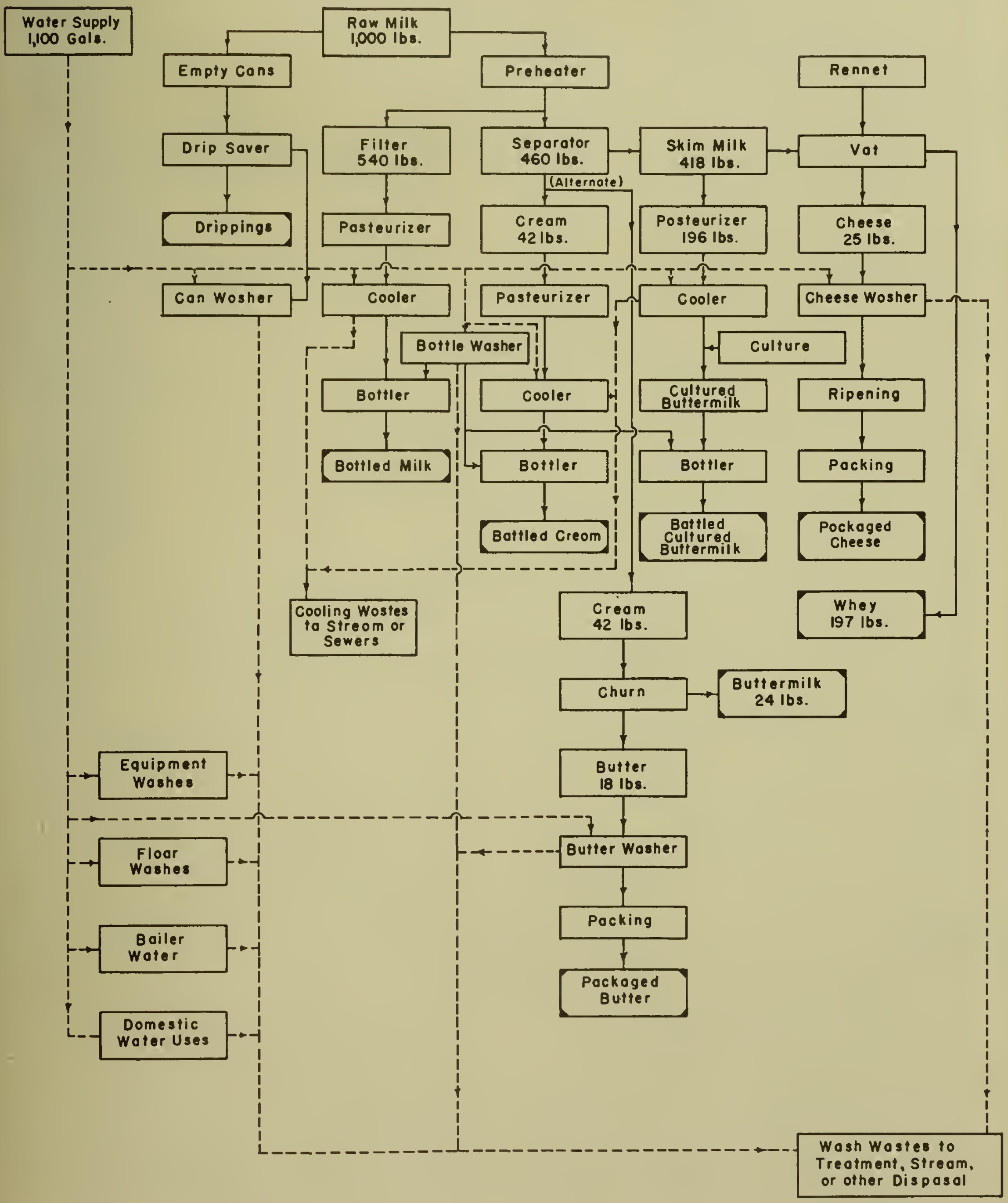
Sanitary Sewage - Discharged to municipal sewer in front of plant.

Remarks - Company does local business. Some expansion contemplated in the near future.

FLOW DIAGRAM

MILK PRODUCTS PLANT

GENERAL DAIRY.



OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

OIL

An Industrial Waste Guide to the Oil Industry

APPENDIX "IX" OF SUPPLEMENT "D"

to the

Final Report

to the

Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract 0-1
Description of Process 0-2
Raw Materials and Products 0-5
Sources of Waste 0-6
Quantity of Wastes 0-8
Character of Wastes 0-8
Pollution Effects 0-13
Remedial Measures 0-15
Oil Field Wastes 0-19
Bibliography 0-26
Note-Taking Form 0-28
Inspection Report 0-29
Flow Diagrams 0-31

List of Tables

0-1 Typical Oil Product Yields for Various Crude Oils as Listed by Gruse 0-6
0-2 Oil Film - The Relation of Thickness, Quantity and Appearance of Floating Oil 0-9
0-3 Oil Refinery Waste - Classification of Substances Found in Wastes from the Oil Refinery Industry, as Prepared by the American Petroleum Institute . 0-11
0-4 Oil Field Brines - Mineral Analyses of Brine Samples from Selected Representative Producing Areas in Kansas 0-21
0-5 Mineral Analyses of Brine Samples from Improperly Plugged and Abandoned Wells in Kansas 0-22
0-6 Oil Field Brines - Toxic Doses of Sodium Chloride for Various Animals as Reported by Ferguson . . . 0-23
0-7 Oil Field Brines - Toxic Sodium Chloride Concentrations in Drinking Water for Various Animals, Computed from Toxic Doses and Water Consumption . 0-23

Abstract

Oil refining processes vary greatly with the type of crude oil being used and the finished products desired. New processes are continuously being devised and old processes changed to meet the shifting demand for various petroleum products. Some refineries merely distill the crude oil to separate the various fractions and sell these after processing to remove certain impurities or objectionable characteristics. The larger refineries "crack" or otherwise change the chemical structure of one or more of the fractions to increase the yield of the more valuable products such as gasoline.

Wastes from oil refineries contain: (a) free and emulsified oil which may form an unsightly film on the surface of the receiving body of water, coat objects with which it comes in contact, retard atmospheric reaeration, occasionally constitute a fire hazard, and generally interfere with normal water uses; (b) substances which may cause tastes and odors in water supplies; (c) substances which tend to deplete the dissolved oxygen content of the receiving body of water; and (d) suspended matter which may form sludge deposits on the bottom of a stream. In general, the oil refinery pollution corrective measures have been directed at the first two types of substances since they are usually of greater importance, and the removal of oil and of substances causing tastes and odors will ordinarily also reduce the oxygen demand and suspended solids content of refinery wastes.

The waste flows from oil refineries are large, averaging 770 gallons per barrel of oil processed at 41 refineries in the Ohio Basin. If the water is not reused, cooling water accounts for about 80 to 90 percent of the waste flow. The B.O.D. of the combined wastes is relatively low, usually ranging from 10 to 30 p.p.m., and the suspended solids content is usually within the range of 25 to 75 p.p.m. Reliable data on sewered population equivalents are limited. The Ohio River Pollution Survey has used values of 600 per 1,000 barrels per day based on B.O.D. and 1200 per 1,000 barrels per day based on suspended solids, as approximations to facilitate comparison of the polluting effects of oil refinery wastes with those from other sources.

Sedimentation and flotation basins for separating the oil, water and settleable solids of the wastes are standard refinery items of equipment. The Committee on Disposal of Refinery Wastes

of the American Petroleum Institute has studied the question of separator design extensively and has developed an efficient separator which is reported to produce an effluent containing only 15 p.p.m. of oil when operating under favorable conditions. Most of the refineries in the Ohio Basin have rather inefficient separators, inadequate in size and operated with little attention.

The removal of emulsified oil or the prevention of emulsions, and the removal of substances causing tastes and odors, can be done most easily and effectively by segregating the offending waste and treating it separately. Numerous methods are available for treating these wastes. One of the most troublesome effluents is the caustic waste from chemical treatment of gasoline and other oils.

Brines from oil fields cause considerable damage to water supplies, agriculture, fish and other aquatic life. The principal methods of disposal are storage with regulated outflow and return of the brines to suitable underground formations. The latter method is preferable but is not, at the present time, universally practicable. The practice is relatively new and further development may extend its applicability. Brine production often can be minimized by proper well operation and reworking to seal off the water.

Description of Process

Crude oil is delivered to the refinery by pipe line, tank cars or tank ships, from which it is transferred to refinery storage tanks and to refinery processes.

Refining of oils consists usually of fractional distillation to separate the various hydrocarbons, application of heat and pressure with or without the use of catalysts to alter the molecular structure of some of the distillation products, and chemical and mechanical treatment of various fractions or products to remove impurities.

The specific processes used vary greatly, depending upon the composition of the crude oil being processed and the products desired. The increasing demand for high test motor fuel and aviation gasoline has brought about the development of numerous processes for increasing the yield of these products.

Crude oils are roughly classified in American practice according to the nature of the residuum left by nondestructive distillation, such as paraffin-base, asphaltic base, or mixed bases containing both.

A paraffin-base crude oil might be refined as follows:

The crude oil is passed through a pipe still into a fractionating tower where the lighter products, as gasoline, kerosene and gas-oil, are taken off and passed to condensers.

The gasoline and kerosene are purified by passage through tanks in which sulfuric acid, caustic soda, plumbite and water washes are variously applied to remove impurities (or their objectionable characteristics), after which the fractions are stored preparatory to blending, further processing, or distribution.

The gas-oil may be treated and stored for distribution as light fuel oil or reprocessed to convert it into gasoline and residual oils. The cracked gasoline is purified and blended with the above mentioned "straight-run" gasoline. The gasoline as finally distributed may contain, in addition to the above, a casing-head gasoline recovered at the well from natural gas or a natural gasoline which is blended in with the refined products.

Distillation of the remainder is then continued to take off a lubricating or wax distillate which is chilled and filter-pressed to remove the wax. The wax is further processed by "sweating" out the remaining oil, after which it is treated, filtered and pressed into cakes for distribution. The oil recovered by sweating, together with the chilled oil passing the filter press, are processed in a rerun still and fractionating tower to yield various grades of lubricating oils which are treated, filtered and stored. These are known as neutral or blending oils.

The residue resulting from the removal of the gasoline, kerosene, gas-oil and wax-distillate, called cylinder stock, contains a wax which is removed by diluting the stock with naphtha, chilling and either settling or centrifuging. This wax is made into petrolatum, used chiefly in preparing ointments, salves, and as a rust preventive. The remaining cylinder stock is cleared of the naphtha by distilling, is filtered through clay to remove resinous and carbon-forming constituents and is used to make heavy automobile lubricants and steam cylinder oils.

In refining some asphalt-base crudes and mixed base crudes, the lighter oils are usually taken off as in paraffin-base crudes.

The remainder is vacuum distilled to produce lubricating oils of various viscosities, which are treated, filtered and stored prior to distribution. The final vacuum residue is used for the manufacture of asphalt.

Other variations in processing, depending on the crude oil being refined, may be used, such as the combined fire and steam distillation of high asphalt crudes which, after the removal of the lighter fractions, leaves a "flux" used as paving asphalt; or the coking distillation of crudes low enough in asphalt to allow good lubricants to be taken off but too high in asphalt for cylinder stock, the final residue being a porous coke.

The chemical treatment of the various products or fractions obtained by physical distillation and crystallization processes is usually applied to remove or change substances contributing undesirable characteristics to the products. The unstable hydrocarbons; sulfur, nitrogen, and oxygen compounds; resins and asphalts; and petroleum acids are responsible for subh objectionable characteristics in the final product as bad color, instability of color, bad odor, gumming and corrosion properties, etc. Catalytic treatment has replaced chemical desulfurization in a number of refineries.

Some lighter fractions resulting from noncracking distillation of good crudes may not require acid treatment. In such cases treatment may consist of a caustic soda wash for removal of hydrogen sulfide and some of the mercaptans, etc., or a more complete treatment consisting of the caustic wash followed by the application of a small amount of sulfur together with a plumbite solution for a more complete removal of mercaptans,etc.

Treatment by sulfuric acid is very common, followed by water and alkali washes, and plumbite sweetening. The acid treatment consists of pumping the fraction into a lead-lined, hopper bottom, closed tank (agitator). Sulfuric acid is added while the charge is agitated by air or recirculation. The sludge formed is allowed to settle and is drawn off. For heavier fractions a very small amount of water or strong alkali solution may be added to facilitate the settling operation. A water wash following this is used to remove some of the acidity due to soluble compounds and sludge retained in the fraction. Sludges, resins, sulfonated hydrocarbons, sulfur dioxide, and weak acid solutions are produced.

An alkali wash follows and removes the remaining sulfuric acid and part or all of its acid esters, oil-soluble sulfonic acids, and naphthenic acids persisting from the crude. These are removed largely as soaps and, together with the colloidally suspended solids, contribute largely to the formation of emulsions that accompany alkali washing. Alkali treatment may be applied in the same agitator or, where heavy, viscous, sticky sludges are formed, the alkali treatment may be applied in a separate agitator to avoid redissolving sludge not drawn off.

Continuous acid treatment of light oils is common practice. Acid sludges and waste caustic solutions result.

Raw Materials and Products

Petroleum from all sources may be generally described as consisting of about 83 to 87 percent carbon, 11 to 14 percent hydrogen, and oxygen, nitrogen and sulfur in amounts varying from traces to 2 or 3 percent. There also may be present inorganic constituents remaining as a few hundredths of a percent of ash on combustion. These may be present as oil-soluble salts of petroleum acids, or as salts dissolved in water emulsified in the oil, probably mostly in the latter form as chlorides of calcium, sodium or magnesium. Nonmetallic elements, such as phosphorus, may occur in organic combinations analogous to that of sulfur.

However, within this narrow range of general composition, a wide variation of product yields is possible due to the amount and distribution of the various homologous series of hydrocarbons composing the raw oil.

In general, the oils show certain characteristics as to composition and specific product yields, depending on the particular locality or field from which they are produced. The particular oil received is routed through a refinery according to its characteristics and economic product yields.

Some of the products and by-products are:

Products: gasoline, kerosene, lubricants, gas-oil and fuel oil, wax, asphalt, petroleum coke.

Miscellaneous: insulating oils, painter's naphtha, pharmaceutical oils, insecticides, cutting (metal work) oils, petrolatum, etc.

Some typical yields, in percent as listed by Gruse, are shown in Table 0-1 on page 0-6.

Table 0-1 Typical Oil Product Yields for Various Crude Oils as Listed by Gruse

Crude Oil	West Va.	Penna.	Average Mid-Cont.		Muskogee	Mexia-Powell
Method of Running	Cyl.	Cyl.	Cyl.	Coke	Flux	Flux
Gasoline & naphtha	38.67	30.59	21.34	21.34	34.92	20.33
Kerosene, etc.	18.37	16.94	9.77	9.77	14.29	28.52
Gas-oil	17.32	24.12	34.13	53.31	16.47	20.13
Neutral (lub. oils)	5.96	4.75	5.88	5.88	4.47	5.26
Wax	1.21	1.46	1.88	1.88	0.68	0.26
Cylinder stock	13.32	14.08	23.50	-	-	-
Coke	-	-	-	4.32	-	-
Flux	-	-	-	-	22.46	21.09

Employee - Raw Material Ratio

Information from 38 plants in the Ohio Basin indicates about 30 plant employees per 1000 barrels (42 gal./bbl.) of crude oil refined per day, but the number of employees varied from less than 10 to more than 100 per 1000 barrels per day.

Sources of Waste

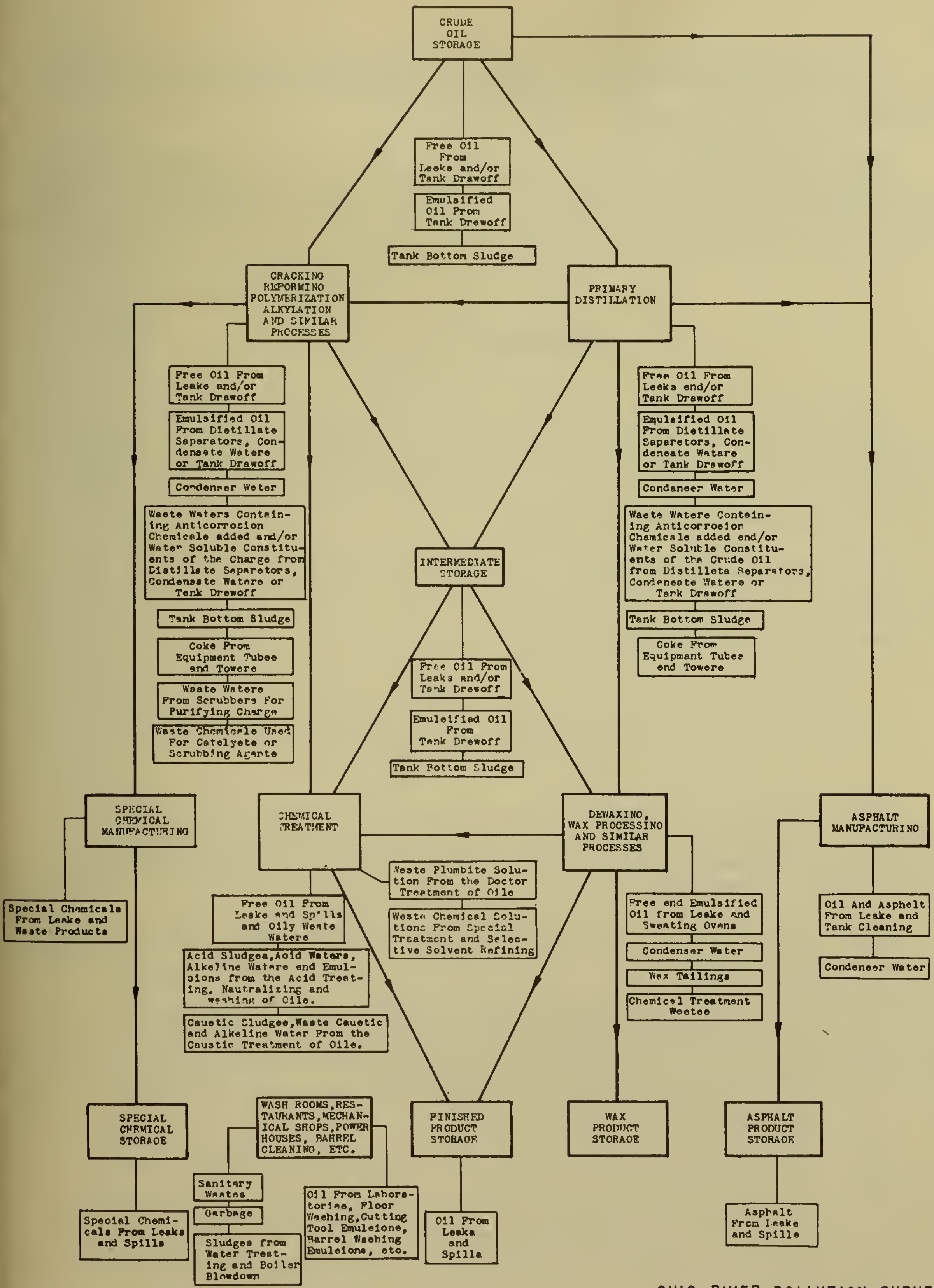
The chart on page 0-7, by Weston and Hart, shows the sources of wastes from petroleum refining.

Receiving, transferring and storing of crudes are sources of escaped free and emulsified oils, and water containing organic and inorganic substances in suspension and solution from: leaks in tanks, piping and appurtenances; cleaning various containers and equipment; draining off water and sediment; and from overflows, spills and boilovers.

Distilling, cracking produce or release organic sulfur and nitrogen compounds, phenols, naphthenic acids and other compounds.

Treating distillates releases liquors and sludges containing escaped oil fractions and the products of the chemical treatment.

WASTES OF PETROLEUM REFINING


CRUDE OIL STORAGE
Free Oil From Leaks and/or Tank Drawoff
Emulsified Oil From Tank Drawoff
Tank Bottom Sludge
CRACKING REFORMING POLYMERIZATION ALKYLATION AND SIMILAR PROCESSES
PRIMARY DISTILLATION
Free Oil From Leaks and/or Tank Drawoff
Emulsified Oil From Distillate Separators, Condensate Waters or Tank Drawoff
Condenser Water
Waste Waters Containing Anticorrosion Chemicals added and/or Water Soluble Constituents of the Charge from Distillate Separators, Condensate Waters or Tank Drawoff
Tank Bottom Sludge
Coke From Equipment Tubes and Towers
Waste Waters From Scrubbers For Purifying Charge
Waste Chemicals Used For Catalysts or Scrubbing Agents
Free Oil From Leaks and/or Tank Drawoff
Emulsified Oil From Distillate Separators, Condensate Waters or Tank Drawoff
Condenser Water
Waste Waters Containing Anticorrosion Chemicals added and/or Water Soluble Constituents of the Crude Oil from Distillate Separators, Condensate Waters or Tank Drawoff
Tank Bottom Sludge
Coke From Equipment Tubes and Towers
INTERMEDIATE STORAGE
Free Oil From Leaks and/or Tank Drawoff
Emulsified Oil From Tank Drawoff
Tank Bottom Sludge
SPECIAL CHEMICAL MANUFACTURING
Special Chemicals From Leaks and Waste Products
CHEMICAL TREATMENT
Waste Plumbite Solution From the Doctor Treatment of Oils
Waste Chemical Solutions From Special Treatment and Selective Solvent Refining
Free Oil From Leaks and Spills and Oily Waste Waters
Acid Sludges, Acid Waters, Alkaline Waters and Emulsions from the Acid Treating, Neutralizing and washing of Oils.
Caustic Sludges, Waste Caustic and Alkaline Water From the Caustic Treatment of Oils.
DEWAXING, WAX PROCESSING AND SIMILAR PROCESSES
Free and Emulsified Oil from Leaks and Sweating Ovens
Condenser Water
Wax Tailings
Chemical Treatment Wastes
ASPHALT MANUFACTURING
Oil And Asphalt From Leaks and Tank Cleaning
Condenser Water
SPECIAL CHEMICAL STORAGE
Special Chemicals From Leaks and Spills
WASH ROOMS, RESTAURANTS, MECHANICAL SHOPS, POWER HOUSES, BARREL CLEANING, ETC.
Sanitary Wastes
Garbage
Sludges from Water Treating and Boiler Blowdown
Oil From Laboratories, Floor Washing, Cutting Tool Emulsions, Barrel Washing Emulsions, etc.
FINISHED PRODUCT STORAGE
Oil From Leaks and Spills
WAX PRODUCT STORAGE
ASPHALT PRODUCT STORAGE
Asphalt From Leaks and Spills

From "The Water Pollution Abatement Problems of the Petroleum Industry" by R. F. Weston and W. B. Hart, the Atlantic Refining Co., Philadelphia, published in Water Works and Sewerage, May, 1941.

OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

Storing, loading and shipping finished products are sources of escaped products and residual products of treatment discharged in or with water draw-offs.

Miscellaneous waters containing oils and solutes may be discharged from gas purification and recovery processes, processes to recover chemical reagents and by-products. Sludges from water treatment are produced.

Quantity of Wastes

Data from 41 refineries in the Ohio Basin indicate the average volume of waste produced to be about 770 gallons per 42-gallon barrel of crude oil refined. This volume includes cooling waters. Variations of from 100 to 2000 gallons were found at different refineries.

The American Petroleum Institute reports that 80 to 90 percent of the total water used by the average refinery is used for cooling purposes only, never coming into contact with petroleum or petroleum products.

Character of Wastes

The combined wastes may contain crude oil and various fractions, and dissolved and suspended mineral and organic compounds discharged in liquors and sludges from the various stages of processing.

Oil may appear as free oil, emulsified oil, and as coating on suspended matter. Ordinarily, waste waters discharged will not contain as much as 0.01 percent (100 p.p.m.) oil. Floating oil is easily seen, even in very small amounts. On a clean water it has been found experimentally to spread to a thickness of one molecule. The relation of thickness, quantity and appearance has been given as follows:

Table 0-2 Oil Film - The Relation of Thickness, Quantity and Appearance of Floating Oil

Approx.thickness of film - inches	Appearance	Approx.quantity (gals.) oil for a spread of one square mile
0.0000015	Barely visible under most favorable light conditions	25
0.000003	Visible as silvery sheen on surface	50
0.000006	First trace of color may be observed	100
0.000012	Bright bands of color are visible	200
0.000040	Colors begin to turn dull	666
0.000080	Colors are much darker	1,332

Laboratory tests indicated that films up to 0.000003 in. thick did not persist on an agitated water surface for more than 5 hours. Tests at sea where a mixture of oil and sea water was pumped overboard indicated that it took 40 to 100 hours to film out to 0.00004 in. and the oil disappeared from the surface in less than 24 hours after this thickness had been reached.

The disappearance of oils from the surface does not necessarily mean the removal of the oil, however, nor are the above filming-out effects strictly applicable to conditions in the relatively limited areas of rivers where it is possible for light films to accumulate in backwaters and slow-moving threads close to the banks.

The emulsions result from contact and agitation of oil and water in the presence of emulsifying agents. Emulsions such as oil-in-water, water-in-oil, or more complicated types as oil-in-water-in-oil may appear in various drawoffs and treatment process discharges. Emulsions of the water-in-oil type, which will separate and usually float but sometimes settle in water, may occur almost anywhere in the refinery. The milky, highly stable emulsions - water in the continuous phase - are usually limited to wastes from treatment of the heavier oil when caustic washes are used for neutralization followed by a water wash as the final step. Emulsions, in time, become free oil, although they may not so appear locally. The usual refinery gravity separator does not take out the more stable emulsified oils. Discharge of emulsifying agents may result in emulsifying oils otherwise removable.

The oil discharged as coating on suspended matter may blanket the stream with an oily sludge which may persist and continue its objectionable oil effects over a long period of time; it may redeposit following removal by freshets, etc., and, with such agitation, release some of the oil to the surface as floating oil.

Substances other than oils, consisting of true solutes, suspensoids and emulsoids of organic and inorganic nature, are present in the water drawoffs and waste products of treatment.

The American Petroleum Institute has classified these constituents according to the refinery units from which they are released. This classification is reproduced in Table O-3 on page O-11.

There is little information published on analyses and production units from which representative characteristics or unit strength equivalents may be presented. Information secured through private communications relative to tests at one refinery indicated approximate weighted average increases in 5-day B.O.D. (difference between raw water and wastes) of 46 p.p.m. prior to corrective measures, 14 p.p.m. following corrective measures and 39 p.p.m. following a change in refining processes.

A two-day test at a refinery processing 5200 barrels per day of crude oil and producing 1.366 m.g.d. of wastes, showed the following results: 5-day B.O.D., 61 p.p.m.; suspended solids, 124 p.p.m.; phenols, 12.8 p.p.m.; and oil, 150 p.p.m. These results indicate sewered population equivalents of about 780 per 1000 barrels per day based on B.O.D., and 1340 based on suspended solids. The separators at this plant were not functioning effectively, as evidenced by the relatively high oil content of the waste. Consequently the sewered population equivalents may be higher than at plants where the separators are efficient.

Limited data from plants in the Ohio Basin indicate the oil content of refinery waste to be from about 10 to 50 p.p.m. where efficient separators are in use, and the 5-day B.O.D. to be less than 50 p.p.m. Suspended solids are usually somewhat

Table 0-3, Oil Refinery Waste - Classification of Substances Found in Wastes from the Oil Refinery Industry, as Prepared by the American Petroleum Institute

Refinery Unit	Native Solutes and Those Present in End Products	Solutes Present which Result from chemical reactions	Naturally occurring emulsoids and Suspensoids, and Those Persisting in End Products	Suspensoids and Emulsoids Resulting from Chemical and Physical Actions
1. Oil storage	a. Organic sulfur compounds.* b. Acids: H_2S, CO_2, organic acids. c. Inorganic salts: NaCl, $MgCl_2$, Fe and Al compounds, $CaCl_2$ $(NH_4)_2S$, etc.	- - - - - - - - - - - - - - - -	a. Suspended matter in tank bottoms. b. Insoluble salts, SiO_2, $Al_2(SiO_3)_3$, S, finely divided substances. c. Asphaltic compounds (in some cases).	- - - - - - - - - - - - - - - -
2. Distillation: A. Straight distillation.	a. Organic nitrogen compounds.+ b. Organic sulfur compounds.* c. Phenol and like compounds. d. Naphthenic acids.	a. Inorganic salts, sulfites, acid sulfites, Na_2CO_3, $(NH_4)_2S$, Na_2S, Sulfates, acid sulfates. b. Acids and alkalies: H_2S, NaOH, NH_4OH, $Ca(OH)_2$. c. $(NH_4)_2SO_4$, $(NH_4)_2S$, NH_4Cl.	Insoluble organic and inorganic salts, S compounds, sulfonic and naphthenic acids, and insoluble mercaptides.	a. Oil-water emulsions from steam in towers, etc. b. Soaps. c. Waxy emulsions d. Oxides of metals.
B. Cracking and distillation.	Same as 2-A.	Same as 2-A with the addition of phenols and phenolic compounds.	a. Suspended coke b. Insoluble salts, FeS, and SiO_2.	Same as 2-A.
3. Treating: A. Sweetening, sulfuric acid, neutralization.	a. Organic sulfur compounds.* b. Organic nitrogen compounds.+ c. Naphthenic acids. d. Phenylates.	a. Organic sulfur compounds. b. Phenolic and sulfonate compounds. c. Weak H_2SO_4 and other acid solutions. d. Weak alkaline solutions. e. Soaps. f. Inorganic salts: $CaCl_2$, Na_2CO_3, Na_2SO_4, NaCl. g. Oxides dissolved in alkaline solutions as PbO, CuO, etc.	a. Suspended matter: PbS, S, S compounds. b. Acid and alkaline sludges. c. Polymers and resins	a. Waxy emulsions b. Oil-water emulsions. c. Inorganic salts: PbS, $CaSO_4$, $CaHPO_4$. d. Soaps. e. Oxides: PbO, Fe_2O_3.
B. Clay	Same as 3-A	Same as 3-A, a,b,c, and f.	a. Suspended clay earth. b. Polymers and resins.	a. Suspended clay, earth. b. SiO_2, H_2SiO_3, $Al(OH)_3$.
4. Recovery A. Gas purification and recovery.	a. Organic sulfur compounds.* b. Organic nitrogen compounds.+	a. Inorganic salts: sulfates, acid sulfates, sulfites, acid sulfites, FeS, $(NH_4)_2S$, Na_2CO_3, Na_2S. b. Mercaptides	Insoluble S compounds and mercaptides.	Suspended Fe and S compounds.
B. Acid recovery.	a. Sulfonates. b. Mineral acids. c. Organic nitrogen compounds.+	a. Inorganic salts, and H_2SO_4, SO_2, SO_3. b. Organic esters.	a. Organic suspensoids: tars. b. Some sulfur compounds.** c. Some nitrogen compounds.++	Acid sludges.
5. Miscellaneous A. Cooling and boiler water treating.	- - - - - - - - - - - - - - - -	Inorganic salts: $BaCl_2$, NaCl, $NaHCO_3$, Na_2SiO_3, $CaCl_2$, $MgCl_2$, Na_2CO_3, Na_2SO_4, Na_2HPO_4, $CaHPO_4$, etc.	- - - - - - - - - - - - - - - -	Insoluble and colloidal compounds: $CaCO_3$, $BaCO_3$, $Ca(OH)_2$, $Mg(OH)_2$, $Be(OH)_2$, $Ca_3(PO_4)_2$.
B. Fire protection.	- - - - - - - - - - - - - - - -	a. Inorganic salts: $NaHCO_3$, Na_2SO_4, $Al_2(SO_4)_3$. b. Organic compounds.	- - - - - - - - - - - - - - - -	- - - - - - - - - - - - - - - -

* Under this caption are included mercaptans, dialkyl sulfides, sulfonates, sulfonic acids, some alkyl and aryl sulfides, etc. Only a few of these compounds will be found in any one type of oil.

+ Under this caption are included amines, some amides, quinolines, and pyridines. Only a few of these compounds will be found in any one type of oil.

** Some alkyl sulfides, thiophenes, etc. Not all of these compounds are found in any one given type of oil.

++ Quinolines, some amides, pyridines, and some aryl amines. Not all of these compounds are found in any one given type of oil.

NOTE - Asphalt and lubricating-oil units have not been included in the separate headings. Straight-run distillation involves the heavier oils, also sulfuric-acid treating embraces that of lubricating oils as well as light oils.

higher than the B.O.D. Most of the oxygen demand occurs during the first day of the 5-day incubation period, indicating that the demand is primarily a chemical one and not due to organic decomposition as in the case of domestic sewage and many industrial wastes.

Phenol content of refinery wastes varies widely since the largest amounts of phenols are in the intermittent wastes. The general average of the continuous wastes appears to be about 10 to 30 p.p.m., but when the intermittent wastes are discharged the content may be several hundred p.p.m. Oeming's studies of Michigan refineries showed that the spent caustic and spent plumbite solutions, which are discharged periodically in very small volume, contain several thousand p.p.m. of phenol.

Sewered Population Equivalent - From the limited data available on the B.O.D. and suspended solids of refinery wastes, it is possible to derive approximate sewered population equivalents. These equivalents, per 1000 barrels of crude oil processed per day, are 600 based on B.O.D. and 1200 based on suspended solids. These values may be in error by more than 100 percent and are useful only as a rough indication of the importance, from a standpoint of oxygen depletion, of refinery wastes as compared with other types of pollution. Although the oxygen-depleting character of refinery wastes has caused problems in a number of instances, other effects of the wastes are usually considered more important.

Pollution Effects

Water Supplies

Surface waters used for domestic water supplies may be made objectionable due to tastes and odors caused by oil and compounds such as phenols, organic sulfur compounds (of which the mercaptans are well known), and complex nitrogenous compounds.

Phenols have produced disagreeable chlorophenol tastes in concentrations as low as 0.001 to 0.02 p.p.m. in the presence of chlorine (as in chlorinated water supplies). The complex organic sulfur group of compounds, chiefly mercaptans, mercaptides, sulfides, disulfides and polysulfides, produce intense and persistent tastes and odors. Baylis reports that ethyl mercaptan has produced a detectable odor in extremely low concentrations and that naphthenic acids have produced a "smoky-oily" odor in a concentration of 0.01 p.p.m. These values, although subject to wide variations, show that extremely small amounts of the compounds may be objectionable.

Oil may cause difficulties at water purification plants by coating filters and other equipment.

Agriculture

Livestock losses have been reported due to refinery waste pollution. Livestock have been reported to develop a taste for crude oil and suffer adverse physiological effects from its ingestion, either because of its laxative properties or its toxicity.

Recreation, Waterfowl, Aquatic Life - Bathing beaches and dependent facilities may be rendered objectionable and useless by oil deposits on beaches, shores and equipment. Pleasure boat owners may object to oil coatings on hulls and equipment and to damage of hull paint. Odors are objectionable in connection with these uses.

Wildfowl die from hunger, exposure or drowning when disabled through saturation of their feathers by contact with floating oil.

Fish and shellfish are reported to acquire objectionable flavors as a result of refinery waste pollution. The destruction of fish and fish food by oil in minute quantities (absence of any film) is apparently a question of varied opinion - however, oil and water extracts have been found poisonous to brown trout. Prevention of absorption of oxygen from the air by oil films is possibly not serious where surface disturbances can break up the film. Concentration on quiet water might form continuous films.

Other materials which are detrimental to fish life are produced or released in refining processes, and their discharge in excessive concentration may cause death or migration of fish. The effects of some of these compounds have been investigated and a summary of various experimental results on these and other compounds is presented by M. M. Ellis.

As Ellis points out, the application of lethality data to specific pollution problems is impossible because of a number of other factors which have important bearing on the subject.

> Hydrogen sulfide - at 10 p.p.m. in tap water caused trout to float on their backs in 15 min.; lethal dosages (no time reported) were 0.086 p.p.m. for brook trout, 3.8 p.p.m. for suckers, 4.3 for aquarium goldfish, 6.3 p.p.m. for carp.
>
> Sulfur dioxide - made trout float helpless at 10 p.p.m. in tap water in 10 min., killed orange-spotted sunfish at 16-19 p.p.m. in tap water in 1 hour.
>
> Phenol - killed goldfish at 51 p.p.m. in distilled water in 1-1/2 to 2-1/3 hours, in 72 hours "or less" at 10 p.p.m. in hard water; 1 p.p.m. was apparently not injurious in 100 hours; trout overturned at 0.4 to 0.6 p.p.m. in 8-1/3 hours; and fishes (unnamed) to whom 16.6 to 20 p.p.m. was lethal lived at 15 p.p.m. but the flesh acquired a phenolic smell.
>
> Naphthenic acids - at 5 p.p.m. killed minnows in 72 hours, perch in 16-23 hours, pickerel in 36-48 hours, and at 20 p.p.m. killed goldfish in 8-16 hours, carp in 26-36 hours.

Excesses of treatment reagents such as sulfuric acid and sodium hydroxide which may be discharged in quantity in spills or intermittent releases may also affect fish life. Sludges may blanket the stream and interfere with spawning.

Miscellaneous - Fire hazard may result where local conditions are favorable to concentration of floating oils. A serious fire due to accidental ignition of floating oil on a mill pond occurred in St. Louis, Michigan, in 1937. New York Bay experiments indicated that an oil of 175° flash point on water at 54° F. could not be ignited by any ordinary means when the thickness did not exceed 0.064 in.(approx. 1,115,000 gal./sq.mi.) Lighter fractions or dilutions might be ignited more easily.

Remedial Measures

Remedial measures as set forth in the discussion by the American Petroleum Institute, regarding plant practices and waste control methods to minimize pollution, consist briefly of:

(1) Reducing oil escape by:
  (a) Careful plant practice to prevent leaks, spills, etc.
  (b) Minimizing emulsion formation,and breaking of emulsions at their source.
  (c) Removal of the floating oil and floating unstable emulsions, or oil from broken emulsions in separators.

(2) Removal of settleable solids in separators and appurtenant settling basins.

(3) Wastes containing other objectionable pollutional constituents are to be isolated close to their sources and measures taken either to change their undesirable characteristics or prevent their discharge to receiving waters in objectionable quantities.

Recovery

The only product commonly recovered by oil refineries at a profit is oil itself. Some sort of recovery of oil is practically universal practice. This is discussed further in a following section. The Chemical Construction Company has developed a process for recovering acid from acid refinery sludges and at least one plant of this type is in operation in the Ohio Basin treating the acid sludge from a number of Pennsylvania refineries. Other possible items for recovery are sulfonic acids, aromatic hydrocarbons, and naphthenic acids.

Control of Oil

The American Petroleum Institute, through its Committee on Disposal of Refinery Wastes, has devoted much attention to the proper design, construction and operation of oil separators, and have published a bulletin (Revised 1941) including recommendations for good practice in handling refinery effluents containing oil. Study and experimentation by the Committee has led to the development of an improved separator with a number of new features, including: two-stage settling; mechanical sludge removal in the first stage; an inlet compartment containing Raschig rings, coarse rock or some other agglomerate to cause film rupture, coalescence and uniform distribution; elimination of the interior baffles which characterized the earlier recommended separator; and improved baffles at the outlet of each settling compartment. Formulas have been developed for determining the dimensions of the various units in terms of the waste flow. It is reported that these new separators, operating under favorable conditions, produce an effluent with as little as 15 p.p.m. of oil.

Unfortunately, relatively few of the oil refineries have installed adequate separators. Many of those surveyed in connection with the Ohio River Pollution Survey were inadequate in size, constructed of temporary materials, or poorly operated and maintained. The Michigan Stream Control Commission reported in 1938 that a survey of Michigan refinery separator practice indicated a tendency toward makeshift installations of less than minimum capacity and of temporary materials of construction, but that where A. P. I. recommendations had been followed and the installations properly operated, relatively little oil pollution was found.

Where local conditions demand more complete oil removal than can be effected by gravity separators, straw, hay, excelsior, coke or clay filters appear to be the most practicable treatment devices. Chemical treatment has been tried experimentally with good results, but the costs are reported to be high because of the large volumes requiring treatment.

Emulsions

The removal of emulsified oil requires segregation and separate treatment of the portion of the waste containing the emulsion. Processes are available for breaking practically any emulsion found in refinery wastes, but the proper process for use in a particular instance must be determined experimentally since the proper treatment for wastes from a given process may vary with the raw material. The American Petroleum Institute's publication, "Disposal of Refinery Wastes, Section I, Waste Water Containing Oil," contains information on the treatment of emulsions.

In addition to wastes containing emulsions, there may be wastes which cause the formation of emulsions in the plant sewers with resulting decrease in the efficiency of the separators. The solution of this difficulty may require the separate treatment of the offending portion of the waste.

Control of Substances Other Than Oil

The control of pollutional constituents other than oil is discussed in detail in the American Petroleum Institute publications on disposal of refinery wastes, by Weston and Hart, and by Black and Klassen. Most of the following is derived from the A.P.I. publications.

Mineral Acidity - The control of anticorrosion activity should be made an important part of the operation of crude-distillation units and rerun stills, so that waste water leaving the operation will be slightly alkaline.

Sulfuric-acid sludges should be handled in closed systems without drainage to plant sewer systems. Use of equipment to accelerate separation of sludge from treated oil to reduce water washing will be beneficial. The Chemical Construction Corporation process for recovery of acid from acid sludges has been mentioned. Sludges may also be burned. Another disposal method consists of hydrolytic separation of the acid which may be concentrated for re-use; the oil and tar and heavy residue may be burned. Stack gases from sludge burning contain sulfur dioxide and malodorous gases, which may be run through a water scrubber, followed by an oil scrubber, for removal of these materials. The resulting oil effluent may be burned and the acidity of the water effluent neutralized with calcined dolomite. Other acid waters may be similarly neutralized.

Caustic Wastes - With the exception of oil, these are probably the most serious sources of pollution from an oil refinery. In addition to being highly alkaline, these wastes contain large amounts of sulfides, mercaptides and other compounds causing tastes and odors. The B.O.D. of the wastes is also high.

A number of methods are available for reducing the amount of caustic wastes. These include catalytic desulfurization processes which minimize but do not entirely eliminate the use of caustic soda, two-stage caustic treatment, regeneration of caustic contaminated with mercaptans by steam stripping, and other methods.

Acidification, either by direct application of mineral acid, where economical, or by use of CO_2 and SO_2 in flue gases applied to the wastes, may be used. Weston and Hart report that acidification with mineral acid is not practiced in most cases. With either method the bulk of the liberated phenolic materially usually appears as an oil layer which may be separated and burned. Further reduction of phenol content may be accomplished by extraction with oil. The oils recovered from acid-sludge may be used in oil extraction. The water portion of the separation may be pumped to a cooling tower or spray pond for aeration, dilution, and absorption in those closed systems, or it may be ponded and released during high stream flows. Weston and Hart report that the above method is not practical in most cases.

Another method of waste or spent-caustic and wash water disposal involves a process used in conjunction with litharge recovery. The process is patented (U.S.Patent No. 1,667,550).

Oeming reports that some Michigan refineries dispose of spent caustic by evaporation, using heat generated from burning of the gases evolved in the cracking process. Pennsylvania reports the use of evaporation or neutralization and "hot blowing" of caustic wastes. The successful use of trickling filters for phenol removal at the Dow Chemical Company plant suggests another possible method of treating phenolic wastes from oil refineries.

Conclusion - This discussion has been made brief intentionally. It is by no means exhaustive. The complexity of the industry and the need for independent treatment of each waste at or near its source makes the problem of abating pollution by refinery wastes one which requires careful study of each plant. Although this may be said of many industrial wastes, it is particularly true of refinery wastes. The constant change in refinery processes further complicates the problem. Relatively few sanitary engineers have the necessary technical background to deal effectively with all of the problems which arise in dealing with refinery wastes. The problem is primarily one for the technologists of the petroleum industry. The publications of the American Petroleum Institute and the articles by Weston and Hart and by Black and Klassen listed in the Bibliography are valuable sources of information on refinery wastes and their treatment.

Oil Field Wastes

Sources of Wastes

Crude oil in waste waters from producing fields may originate from water drawoffs, apparatus cleaning, and from leaks, breaks, spills and overflows in connection with pumping, conveying and storage of oil at the field. Separation of oil from water or brines results in losses of free and emulsified oils.

In abandoned fields the wells are a potential source of escaped oil which may be forced out with brines and water through faulty plugging or capping of wells.

Brine-bearing formations may overlie or underlie oil-bearing formations. Effort is made to close off these sources by plugging such strata and by bottom-plugging or close control of pumping rates to minimize "coning" of underlying brines at the well. However, due to intimate contact of brine and oil in some producing horizons or ineffectiveness of the above, or both, brine is often produced with the oil. The brine and oil are separated by gravity and the brine disposed of.

The brines may reach strata ordinarily carrying fresh water by migrating to these strata in the oil well because of faulty plugging of various porous formations, corroded casings, or improperly sealed shoulders at casing ends.

Where separated brines are ponded, they may reach streams or wells as a result of seepage, leaks, breaks and overflows. The brines may also be discharged directly to watercourses.

Other Wastes - Processing of natural gas and gasoline at the field to produce casing-head gasoline is a source of wastes probably of the nature of refinery wastes.

Character of Wastes

The wastes consist of crude oil, suspended matter, and brines of widely varying composition, together with the impurities and products of chemical treatment of casing-head gasoline where the gas is processed.

The escaped oil may consist of free floating and emulsified crude oil and oil-coated sediment.

The brines consist chiefly of chlorides of sodium, magnesium and calcium, and not uncommonly sulfates and bicarbonates. Rarer salts such as iodides and bromides may appear in small amounts. The specific gravity of brines ordinarily ranges from 1.001 to 1.175, although as high as 1.205 has been found (sea water has a specific gravity of about 1.025).

Tables on pages 0-21 and 0-22 show some chemical analyses of oil field brines in Kansas, as reported by Schmidt and Wilhelm.

Pollution Effects

Domestic Water Supplies - The effect of oils has been discussed under refinery wastes. The brines may increase the chloride content and hardness of receiving waters to an objectionable degree. The U. S. Public Health Service has recommended 250 p.p.m. chlorides and 1000 p.p.m. total solids as upper limits in the drinking water standards for interstate carriers. Some municipalities may tolerate higher values for these. Information from the Kansas State Board of Health indicated that when chlorides approach 500 p.p.m. a community usually attempts to find a new water supply. The hardness contributed by brine pollution may add considerably to the expense of treatment. A number of municipalities have been forced to develop new sources of water supply because of brine pollution from oil fields.

Livestock - Actual poisoning by oil field brines is reported to be rare. The laxative effects are more common, and loss due

Table 0-4, Oil Field Brines - Mineral Analyses of Brine Samples from Selected Representative Producing Areas in Kansas.

Radical	Concentration in p.p.m.				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Calcium	1,193	1,507	9,800	4,420	12,888
Magnesium	346	428	4,290	2,230	2,510
Sodium	8,260	15,200	63,275	9,325	55,780
Bromide	32	48	633	-	376
Carbonate	0	0	0	0	0
Bicarbonate	644	339	94	156	43
Sulfate	1,578	966	0	10	457
Chloride	12,750	23,080	127,220	28,600	115,580
Total Solids	25,210	44,820	248,600	52,640	210,550

Sample 1 - from siliceous limestone at about 3,250 ft. depth.

Sample 2 - from dolomite horizon at about 3,375 ft. depth.

Sample 3 - from Kansas City limestone at about 2,600 ft. depth (same field as sample 2 but from a different producing horizon).

Sample 4 - from the Viola limestone at about 3,350 ft. depth.

Sample 5 - from producing-sand horizon. This sand found at about 3,200 ft. depth.

Table 0-5, Mineral Analyses of Brine Samples from Improperly Plugged and Abandoned Wells in Kansas.

Radical	Concentration in p.p.m.			
	Sample a	Sample b	Sample c	Sample d
Calcium	538	7,440	796	2,200
Magnesium	73	2,125	793	2,212
Sodium and potassium	25,291	43,020	19,800	26,530
Carbonate	1,883	0	0	0
Bicarbonate	-	81	995	316
Sulfate	3,851	4	932	3
Chloride	34,996	85,765	33,000	51,000
Bromide	-	252	3.5	209
Iodide	-	6	-	4
Total Solids	-	140,460	63,190	83,700

Sample a - water from 743 ft. deep brine well flowing 250 gals./min.--contaminated 4 fresh-water wells in vicinity and increased creek chloride content from 36 p.p.m. to 72 p.p.m. Analyses include silicia, 2 p.p.m.; iron, 2.4 p.p.m.; volatile and organic, 1.5 p.p.m.

Sample b - from an improperly abandoned well on bank of creek - casing stands full of brine and overflows into creek.

Sample c - from flowing brine well - drilling operations were shut down at 2,300 ft.,well flowed brine through 6 inch casing for many months until drilling operations were resumed - well was finally plugged.

Sample d - from improperly plugged and abandoned well - brine flows by heads from gas pressure. Analyses also include 68 p.p.m. barium.

to prolonged purgative action and other physiological effects of such waste have been reported. Table 0-6 shows the toxic doses of NaCl for various animals, as reported by Ferguson, and Table 0-7 shows toxic sodium chloride concentrations computed from these doses.

Table 0-6, Oil Field Brines - Toxic Doses of Sodium Chloride for Various Animals as Reported by Ferguson.

	Cow	Horse	Pig	Sheep
Toxic dose of NaCl	4-8 lbs.	2-3 lbs.	7-8 oz.	4½-8 oz.
Water Consumption:				
Normal, gal./day	12	10	2	1
Max.Prob.gal./day	25	20	3	2

Table 0-7, Oil Field Brines - Toxic Sodium Chloride Concentrations in Drinking Water for Various Animals, computed from Toxic Doses and Water Consumption.

Animal	Toxic NaCl Content in p.p.m.	
	Normal Water Consumption	Maximum Probable Water Consumption
Cow	40,000 to 80,000	19,200 to 38,400
Horse	24,000 36,000	12,000 18,000
Pig	26,300 30,000	17,500 20,000
Sheep	33,800 60,000	16,900 30,000

Approximately one pound of either sodium chloride, sodium sulfate or magnesium sulfate is considered a purgative for mature cattle.

Vegetation is killed when oil-field brines are allowed to flow for a considerable time over the ground surface, the damage depending on time as well as brine concentration and composition. Many abandoned leases subjected formerly to the overflow of salt water are now cultivated.

Previously damaged soil may be reclaimed in time by leaching out of various salts by rainfall.

Recreation, Fish, Wildfowl - The effect of the oil on recreational uses of streams, fish life and wildfowl has been discussed under refinery wastes. The brines might cause migration of fish to fresher waters.

Remedial Measures

Careful operating practices in producing fields, such as the proper sealing off of porous strata and casing joints, keeping casings in good repair, and careful maintenance and operation of brine ponds to prevent leaks, breaks and overflows, will help minimize not only the amount of brine produced with the oil but will help prevent brines escaping to other formations or over the surface.

Solar evaporation, or evaporation and seepage, are satisfactory in only a few special instances. Relatively few of the oil-producing areas are in sufficiently arid regions to make solar evaporation very effective, and seepage is usually to be discouraged because of contamination of underground water by brines. Large pond areas are required for this method of disposal.

Evaporation for the recovery of salts has proved practicable in a few instances where the brines contained relatively large amounts of the more valuable halides. It has not been attempted on a large scale and does not hold much promise as a solution of the problem in general.

Storage and regulated release was one of the first methods to be tried for controlling brine pollution, and it remains the standard practice in a number of fields. The shortcomings of this method are numerous. It does not reduce the total amount of brine entering the streams; it requires considerable areas for storage ponds; breaks in the dikes used to form the ponds or accidental spills can cause very damaging surges of brine in the streams; the soil must be relatively impervious to prevent pollution of underground water by seepage from the ponds; careful regulation of the discharge from the ponds must be provided and, if there are a number of disposal systems in a given drainage area, some supervising agency must be provided to regulate the outflow from the disposal ponds in accordance with the ability of the stream to receive the brine without undue pollution.

In spite of these difficulties, regulated discharge of oil-field brines is the most satisfactory disposal method available at present in a number of areas. Much of the success or failure depends on the care and intelligence with which the discharge of brines is regulated.

Underground disposal of oil-field brines is the most satisfactory method from the standpoint of pollution prevention or abatement. Investigations of this method have been carried on for a number of years as a co-operative project by the U. S.

Bureau of Mines and the Kansas State Board of Health, and systems for returning brines to subsurface formations are in successful operation in many states, including Kansas, Oklahoma, Illinois and Michigan. The Illinois State Health Department requires reinjection of oil-field brines wherever large quantities are produced. Suitable subsurface formations are lacking in some areas, so this method is not universally applicable at present.

Upon release at the surface, the carbonates and iron compounds in the brine are precipitated and must be removed in order to prevent clogging of the formation into which the brine is to be injected. This is usually done by sedimentation and filtration. The cost of conditioning the brine may be considerable.

The cost of an underground brine disposal system in Illinois is reported to be from $15,000 to $20,000, including about $7,000 for drilling, casing and cementing the well. The remainder of the cost is for the collecting and treating facilities. One system of this type may serve a number of wells.

Underground disposal of oil-field brines is a relatively recent development, and the technique is steadily being improved as its use becomes more widespread. Since it is the most promising of the various methods of brine disposal, it is to be hoped that further experience may extend its applicability to areas where other methods must necessarily be used at the present time.

Separators for preventing the escape of oil are necessary in the oil fields as well as at refineries. Limited data on natural gasoline plants indicates that these are seldom important as sources of pollution. Water is used primarily for cooling. Separators are usually necessary and, if the gasoline is treated chemically, wastes similar to those from the same processes in a refinery will be produced.

Bibliography

1. American Petroleum Institute, Committee on Disposal of Refinery Wastes. "Disposal of Refinery Wastes." Section I, Waste Water Containing Oil (1941 Revision); Section II, Waste Gases, Vapors, Sludges and Dusts (1938); Section III, Waste Water Containing Solutes (1935).

2. Baylis, J. R. Elimination of Taste and Odor in Water. McGraw-Hill (1935).

3. Black, H. H., and Klassen, C. W. Industry Abates Stream Pollution, Part III. Sewage Works Engineering 12, 215, (1941).

4. Boyce, E. Disposal of Brines from Oil Drilling and Petroleum Operations. Journal American Water Works Association 29, 362, (1937).

5. Buffalo Sewer Authority. Unpublished data.

6. Chicago Regional Planning Ass'n. and Bureau of Engineering, Department of Public Works, Chicago. Characteristic of Oil Refining Wastes as Related to Objectionable Tastes in Public Water Supplies of the Chicago Metropolitan Area. Mimeographed c. (1932).

7. Cruse, W. A. Petroleum and Its Products. McGraw-Hill (1928).

8. Curran, C. E. Proceedings North American Wildlife Conference, (Feb. 3-7, 1936).

9. Ehlers, V. M. Private communication.

10. Ellis, M. M. Detection and Measurement of Stream Pollution. U. S. Bureau of Fisheries Bulletin No. 22 (1937)

11. Ferguson, H. F. Oil Pollution and Refinery Wastes. Sewage Works Journal 7, 104 (1935).

12. Galtsoff, P. S. Oil Pollution in Coastal Waters. Proceedings North American Wildlife Conference (Feb. 3-7, 1936).

13. Harmon, B. Contamination of Ground-Water Resources. Civil Engineering 11, 345, (1941).

14. Hart, W. B. Private communication.

15. Humphreys, W., and Rawn, A. W. Oil Field Waste Water Disposal. Water Works and Sewerage 87, 341, (1940).

16. Kirwan, M. J. Use of Mud Fluid in Rotary Drilled Wells. Oil and Gas Journal (May 29, 1934, p.59).

17. Klassen, C. W. Private communication.

18. Lincoln, F. C. The Effect of Oil Pollution on Waterfowl. Proc. North American Wildlife Conference (Feb.3-7, 1936).

19. Michigan Stream Control Commission, Fourth Biennial Report (1937-38).

20. Oeming, L. F. The Oil Refinery Waste Problem in Michigan. Michigan Stream Control Commission (1939) (unpublished).

21. Schmidt, L., and Wilhelm, C. J. Contamination of Domestic Water Supplies by Inadequate Plugging Methods or Faulty Casing.

22. Schmidt, L., and Wilhelm, C. J. Theory and Practice in the Underground Disposal of Oil Field Brines. Proceedings of the 21st Texas Water Works and Sewage Short School, College Station, Texas, (1939), p.82.

23. Swigart, T. E., and Beecher, C. E. Manual for Oil and Gas Operations. U. S. Bureau of Mines Bulletin No. 232 (1923).

24. Taylor, S. S., Holliman, W. C., and Wilhelm, C. J. Study of Brine-Disposal Systems in Illinois Oil Fields. U. S. Bureau of Mines, R. I. 3534 (1940).

25. U. S. Public Health Service. Unpublished data.

26. Weston, R. F., and Hart, W. B. The Water Pollution Abatement Problems of the Petroleum Industry. Water Works and Sewerage 88, 208, (1941).

OIL REFINERY WASTES (Not an Actual Plant)

Plant Smith Oil Co. State Va. Ref.No. K 95.6

City Glen Ferris County Fayette Main Watershed Kanawha

Address 18 Shore Rd. Sub-watershed " Direct "

Informant A.B. Brown Title Supt. Principal Product Oil

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	168	365	175
Maximum	—	—	210

Seasonal variation Fairly steady operation

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	City	225		
Industrial				
Cooling	River	4,500,000		

RAW MATERIALS:- Crude oil 7,000 bbls./day average (42 gal./bbl.)

Reclaimed oil (Separator) 50 bbls./day Other Nat. gasoline 360 bbls./day ave.

PRODUCTS:- Gasoline 5,000,000 gal./mo. Fuel ~~oil~~ Kerosene 17,000 bbls./mo.

Lub.oil None at present Other Indus. Asph. 29,000 bbls./mo.

WASTES:- Quantity Ave. 4.5 m.g.d. How estimated Pump ratings

Character:- Washings Gasoline & Kerosene Acid Sludge removed in tank cars

Process Alkali Returned to treatment from ponds.

Water seal Small amount Other

Possible spills Yes - reported to be seldom.

Skimming basin 2 Bays 70' x 10' x 7' deep.

Analyses:- Number Date By whom

Appearance

OUTLET:- Where to All 4 outlets to Kanawha River.

Description:	Size and Shape	Material	Location	Elevation
1.	2 - 8"	C.I.	Skimming	Basins to River
2.	2 - 12"	C.I.	Cooling	Water to River
3.				

Gaging possibilities Poor at River (pipes submerged) can gage skimming basins

Conditions below outlet: Color Some floating oil near outfalls.

Turbidity Deposits None evident.

SANITARY SEWAGE: Disposal To city sewers Persons tributary 185 average.

REMARKS Some taste complaints, maintenance could be improved.

Survey by John Q. Doe Date 10-10-1939

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI,OHIO

INDUSTRIAL WASTES (Not an actual plant)

River Mileage Index No. K 95.6

Type of Plant Oil Refinery State W.Va.

Name of Plant Smith Oil Co.

Municipality Glen Ferris Main Watershed Kanawha

County Fayette Subwatershed "Direct"

Address 18 Shore Rd.

Source of Information A.B.Brown, Supt.

Plant Operation:- Straight and Cracking Distillation.
168 hrs. per week, 365 days per year.
Average 175 plant employees; 10 office employees.
Maximum 210 " "

Seasonal Variation:- Fairly steady operation.

(Survey report continued on next page)

Survey by John Q. Doe Date 10-10-39

Sewered Population Equivalent Computation:-

Factors used per 1,000 bbls. crude oil processed per day.

B.O.D. 600 Suspended solids 1,200

Sewered population equivalent* based on B.O.D. 4,200

Sewered population equivalent* based on suspended solids 8,400

emarks:

omputation by: John Jones Date Oct.17,1939 Cincinnati Offic

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
* Rounded to nearest two significant figures.

K 95.6

Smith Oil Company,
Glen Ferris, W. Va.

Water Supply - Drinking water from city - 225 g.p.d. ave. Industrial and cooling water from Kanawha River - 4,500,000 g.p.d. ave. Boiler water treated.

Raw Materials - Average 42 gal. bbls. per day:

Crude oil	7,000
Reclaimed oil (separator)	50
Natural gasoline	360

Products - Average monthly quantities:

Gasoline	5,000,000 gals.
Furnace Oils & Diesel Fuels	29,000 bbls.
Kerosene	17,000 "
Industrial Asphalt	29,000 "
Lubricating Oil	None at present.

Wastes - Average 4.5 m.g.d.
Washings - Gasoline and kerosene.
Water seal - Small amount.
Acid sludge - Removed in tank cars.
Alkali - Returned to treatment from ponds.
Possible spills - yes, reported to be seldom.
Skimming basins - 2 bays 70' x 10' x 7' deep.

Outlet - 2 - 8 inch cast iron pipe outlets from skimming basins to river.
2 - 12 inch cast iron pipe outlets for cooling waters.
Gaging possibilities poor at river (pipes submerged). Can gage skimming basins.

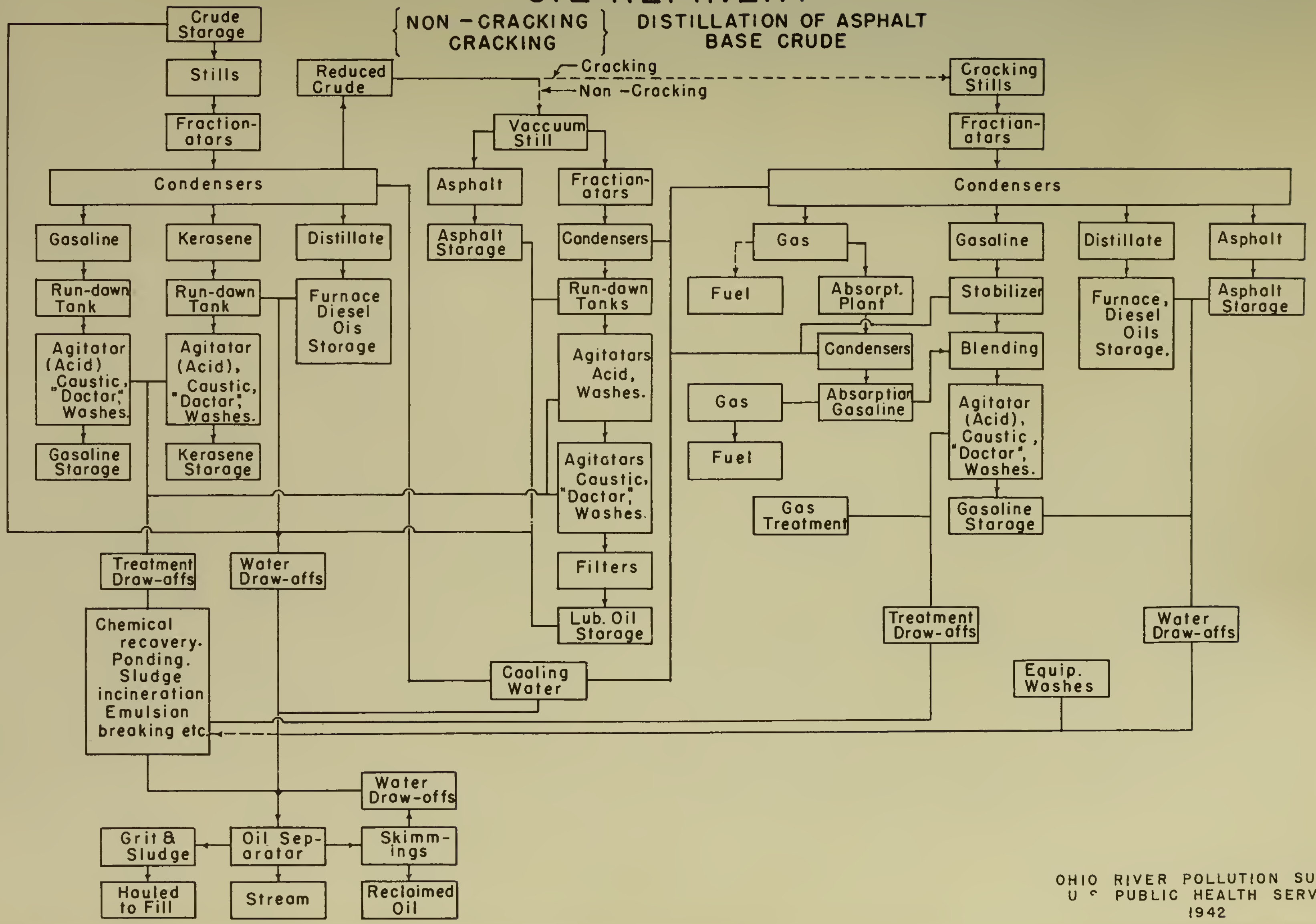
Sanitary Sewage -To city sewers.

Remarks - Floating oil near outfalls - no deposits evident - some taste complaints - maintenance could be improved.

FLOW DIAGRAM

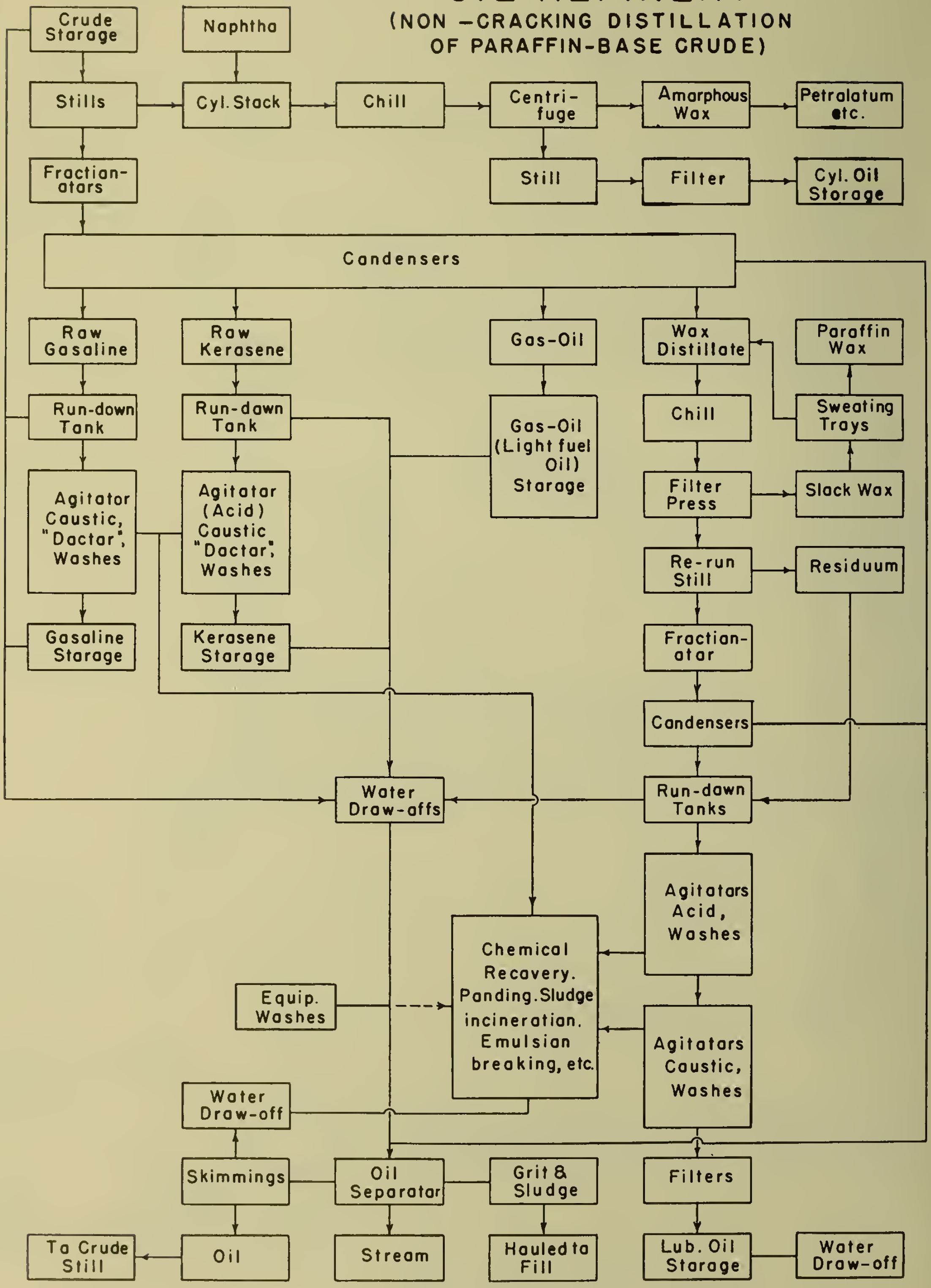
OIL REFINERY

{NON – CRACKING / CRACKING} DISTILLATION OF ASPHALT BASE CRUDE



OHIO RIVER POLLUTION SURVEY
U S PUBLIC HEALTH SERVICE
1942

FLOW DIAGRAM
OIL REFINERY
(NON-CRACKING DISTILLATION OF PARAFFIN-BASE CRUDE)



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

PAPER

An Industrial Waste Guide to the Paper Industry

APPENDIX "X" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract P-1
Description of Process P-2
Raw Materials and Products P-6
Sources and Quantity of Wastes P-7
Character of Wastes P-8
Pollution Effects P-11
Remedial Measures P-12
Bibliography P-16
Note-Taking Form P-18
Inspection Report (Pulp Mill) P-19
Flow Diagram (Pulp Mill) P-21
Flow Diagram (Recovery Processes) P-22
Note-Taking Form P-23
Inspection Report (Paper Mill) P-24
Flow Diagram (Paper Mill) P-26

List of Tables

P-1 Number of Employees, Waste Flows, Sewered Population Equivalents, and Typical Analyses for Pulp and Paper Mills P-1
P-2 Relationship of Raw Materials, Pulp and Strawboard Mills P-6
P-3 Ratio of Employees to Products P-7
P-4 Average Waste Discharges per Ton of Product . P-8
P-5 Sewered Population Equivalents and Typical Analytical Results P-11
P-6 Estimated Cost of Chemical Precipitation . . . P-15

Abstract

Paper manufacturing divides itself into two steps, pulping and paper making. In a pulp mill the raw material, generally wood, cotton or linen rags, straw, hemp, esparto, flax, jute, or reclaimed paper, is reduced to fibers and these are refined, sometimes bleached, and dried. At the paper mill various combinations of pulps, loading materials, and finishes are prepared and rolled into sheets to give the final product. Loading materials or fillers generally used are clay, talc, gypsum, precipitated calcium sulfate, or barium sulfate. The more commonly used pulps are groundwood, soda, sulfate or kraft, and sulfite.

The chief liquid wastes from the pulping process of the paper industry are the digester liquors. Other wastes are from sawing, barking, and chipping operations; wash waters; screens, rifflers, knotters, and thickeners; and bleach and bleach washes. Paper making process wastes come mainly from the beaters, regulating and mixing boxes, and paper machines. Fiber losses in paper making may vary from 0.1 to as high as 20 percent, generally averaging around 3 percent. Number of employees, approximate flows, sewered population equivalents, and typical analyses for pulp and paper mills are shown in Table P-1.

Table P-1 Number of Employees, Waste Flows, Sewered Population Equivalents, and Typical Analyses for Pulp and Paper Mills.

Product	Number of Employees	Wastes in Gals.	Sewered Pop. Equivalent		Typical Analyses	
			B.O.D.	Susp. Solids	B.O.D.	Susp. Solids
	Per Ton of Product Daily				p.p.m.	
Pulp Mills						
Groundwood	250	5,000	16	-	645	-
Soda	300	85,000	460	6,100	110	1,720
Sulfate (Kraft)	-	64,000	390	-	123	-
Sulfite	310	60,000	1,330	-	443	-
Misc. Paper-no bleach	440	39,000	26	520	19	452
" " with bleach	460	47,000	40	220	24	156
Paperboard	210	14,000	97	445	121	660
Strawboard	140	26,000	1,230	1,920	965	1,790
Deinking-Used paper	-	83,000	1,250	-	300	-

Remedial measures may consist of by-product recovery, waste treatment, or a combination of both. Bark and sawdust at pulp mills are recovered by screening, flotation, or sedimentation and then dried and incinerated for heat recovery. Bark chips may be leached and, after washing and grinding, be mixed with kraft paper to form laminated pressboard. Fiber is recovered from washers and thickeners by save-alls. Sulphate process black liquors are processed for recovery of chemicals and heat.

Sulfite black liquor presents the greatest pollution problem in the paper and pulp industry. It may be treated either by the Howard process, a three-stage precipitation method using a caustic lime reagent or by the Paulson process, utilizing multi-state evaporation. Neither of these processes has proven to be entirely satisfactory. Although a high B.O.D. reduction has been claimed for the Howard process, an actual installation has shown a maximum reduction of only about 45 percent. By-products suggested by other investigations include adhesives, fertilizers, alcohol, tanning liquor, dye bases, and road binders. Studies have been made on the purification of mixtures of sewage and sulfite waste liquors by the activated sludge method. Satisfactory results were obtained with sewages containing up to 6 percent of Howard process effluent and up to 10 percent of raw calcium-base sulfite liquor.

Chemical precipitation, ponding, filtration, and aeration have also been applied to the treatment of paper mill wastes with varying degrees of success.

Description of Process

Paper consists basically of cellulose fibers formed or matted into a sheet. The choice of pulp loading and finishing materials is limited by the particular use for which the product is intended. The process divides itself into two steps, pulping and paper making, and a complete plant may include either or both of these steps. In a pulp mill the raw material is reduced to fibers and these are refined, perhaps bleached, and dried. At the paper mill various combinations of pulps, loading materials, and finishes are prepared and rolled into sheets to give the final product.

Pulping Processes

Raw materials are reduced to fibrous pulp by mechanical or chemical means. When wood is used in either case, it is sawed to size and barked.

Groundwood Pulp - Mechanical or groundwood pulp is prepared by grinding the wood on sandstone or emery wheels, from which it is water carried through screens. This pulp contains lignin and resinous matter which discolors it in the light. The fibers are short and do not mat well together. It is generally used for making cheaper grades of papers, such as newspaper, and in combination with other pulps.

Chemical Pulps - Chemical pulps are usually prepared by the soda, sulfate or kraft, or the sulfite process. In all of these the wood is reduced to chips and screened to remove dust. The principal differences in their manufacture are in the method of digestion and in the chemicals used. These are as follows:

Soda pulp is generally made with soft woods such as poplar, cottonwood, and basswood. The digester is loaded with three to five cords of chips; a caustic soda solution, produced by treating soda ash with lime, is run in and the charge boiled for eight to ten hours under steam pressure. Non-cellulose matters, such as lignin and resins which are made up largely of organic acids, are decomposed or combined with the soda. The fiber is also attacked by the alkali, resulting in a weak fiber.

Sulfate or kraft pulp is made using coniferous wood chips which are boiled from four to seven hours with sodium sulfide, hydroxide, sulfate, and carbonate. The first two of these chemicals are active in the disintegration. The sulfide is reduced by the reduction of sodium sulfate and the hot alkali sulfide dissolves the lignin and other non-cellulose matter, leaving a very strong fiber.

Sulfite pulp is made with coniferous wood chips which are placed in a closed vessel, or digester, and treated with a solution of calcium bisulphite under a pressure of about 70 pounds and a temperature of 325° F. There are two cooking methods in general use, the Mitcherlich, or slow cook, method and the Ritter-Kellner, or quick cook, method. In the Mitcherlich process heating is done by passing steam through coils placed inside the digester. The conventional heating process for the quick-cook digester has been to blow the steam directly into the vessel. In up-to-date practice, however, the heating is done indirectly by means of heat exchangers placed outside the cooker and the cooking acid made to circulate from the top of the digester, through the heat exchanger, and into the bottom of the digester, or vice versa. The chief advantages are that no dilution of the cooking acid takes place, thus allowing the cooking process to be done at a lower temperature, the pulp quality is better, and a higher yield is obtained.

Following digestion by one of the various methods described, wood pulps are blown into a closed blow pit where the black liquor is drained off to waste or recovery. The drained pulp is washed either in the pit or in a wash tank, although some plants drain and wash in the digester. The wash waters may then be wasted, stored and re-used, or sent through a recovery process. The unbleached fibers, together with impurities, knots, clumps, and undisintegrated matters are further processed as follows:

Screen, Riffler, Knotter - After digestion and washing, the pulp is stored in a large stock chest from which it flows at a uniform rate through one or more of these devices. Knots and other disintegrated matter are removed, some of this material being returned to the pulp stream after passing through a Jordan, or refining machine.

Thickener - The pulp is partially dewatered by passage through the decker, a cylindrical screen revolving across the pulp stream. This picks up the pulp from the screen and passes it to the bleach.

Bleaching - The thickened pulp is agitated in a weak solution of calcium hypochlorite, which is either heated or has acid added to it to speed up the reaction. A thorough washing follows. Sulfate pulps are difficult to bleach and generally find best use in the manufacture of strong brown wrapping papers. The bleached pulp is dried and marketed or passed on wet to the paper mill.

Paper Making

Wood pulps, produced either mechanically or chemically, are used in combination with rags, straw, hemp, esparto, flax, jute, and reclaimed paper as raw materials. The steps involved in the preparation of the material for the paper machine are as follows:

Beaters - The pulp or combination of pulps, together with the fillers, sizing, and dyes are disintegrated and mixed in the beater, or Hollander. The filler which may be clay, talc, gypsum, precipitated calcium sulfate, or barium sulfate, is added to improve the surface of the paper and to increase its opacity. The sizing may be any one of various glutinous materials and is used to fill the pores. In this machine the materials pass under a rotating cylinder equipped with dull knives which beat or break up the bunched fibers and through repeated cycles effect a thorough mixing of the constituents. Washing of pulps prior to mixing is sometimes done in the beater by the use of an appurtenant revolving screen.

Refiners - The pulp mixture passes through a Jordan, consisting of a tapered knife-equipped cylinder rotating within a close fitting casing in which knives are embedded. This apparatus cuts the fibers to the size desired.

Stuff Chest, Regulating Box, Mixing Box - These devices are used for storing the pulp, regulating the water content of the mixture, and mixing to insure uniform consistency, respectively.

Screen - Lumps and slime spots are removed from the pulp mixture by passing it through a vibrating tank in which a revolving screen intercepts these impurities.

Paper Machine

After preparation, the pulp is evenly distributed across a traveling belt of fine screening, or Fourdrinier wire, and carried to the rolls. The water contained in the prepared pulp is called white water. A part of this is lost in the Fourdrinier wire. A screen roll, or dandy, lightly eliminates inequalities at the end of the wire travel, a suction roll removes more white water, the sheet is passed through press and drying rolls, and finally to the finishing rolls, or calender, after which it is wound on reels.

Strawboard

In the manufacture of strawboard, straw and lime are placed in a closed vessel and subjected to cooking with steam under a 40-pound pressure for 12 hours. The resultant stock of softened woody fiber is allowed to drain for 24 hours and then run through washers to remove the lime. As it comes from the washers, the material is run into vats, where it is mixed with large quantities of water and passed over hollow cylinders having fine wire-cloth surfaces which allow the water to escape. The fiber is then taken by woolen felts that are pressed down on the surface of the cylinder, making a web of paper on the felt. The pulp is next carried simultaneously over and under a double train of steam-heated hot rolls. As it passes through the train it is constantly pressed and dried, and finally separated from the cloth support. It then goes to the trimming machine and is cut into sheets of proper size. Just before trimming the board may be coated on one or both sides with a thin paper facing or finish.

Raw Materials and Products

Although considerable difference exists in the ratio of raw material to product yield for individual plants it is possible, in the case of pulp mills, to arrive at some general relationships between them. These general relationships are given in Table P-2.

Table P-2 Relationship of Raw Materials, Pulp and Strawboard Mills

Raw Materials	Unit per Ton Product	Dry Pulp				Strawboard
		Groundwood	Soda	Sulfate (Kraft)	Sulfite	
Wood	Cords	1.0	-	-	2	-
	Tons	-	2.0	2.4	-	-
Straw	Pounds	-	-	-	-	2,800
Lime	"	-	500	325	175*	180
Limestone	"	-	-	-	350*	-
Sulfur	"	-	-	-	250	-
Soda Ash	"	-	250	-	-	-
Sodium Sulfate (Salt Cake)	"	-	-	450	-	-

* Applied either as lime or limestone.

Due to the great variability of raw materials and final products in paper manufacturing, it is difficult to show even general relationships between them. Some of the principal papers manufactured are as follows:

Printing papers - These contain large amounts of loading materials and are generally made from wood pulps.

Newspaper - This is made chiefly from a mixture of mechanical and unbleached sulfite pulps.

Wrapping papers - They are made from straw, jute, hemp, old rope, and colored rags. Sulfate pulp gives a particular strong wrapping paper. This product is sized and sometimes calendered but seldom bleached.

Writing Papers - The best materials, generally wood pulps, with or without rags are used for these. They are highly sized and carefully calendered.

Blotting and tissue papers - Both of these are unsized and unfilled. Blotting paper is loosely felted and thick. Tissue papers are made from long fibers, principally hemp and cotton.

Parchment paper - Unsized paper is treated with sulfuric acid and glycerine, after which it is washed, treated with dilute ammonia and given a final wash.

Impervious wrapping paper - This is produced by a long continued beating of pulp or rags in the Hollander until all fibers are broken down into a gelatinous mass. When run through the paper machine a thin transparent paper results. Its chief use is for wrapping butter, confectionery, and other food products.

Table P-3, showing ratios of employees to products for paper mills, is based mainly on plants in the Ohio River Basin.

Table P-3 Ratio of Employees to Products.

Product	Number of Employees per 100 Tons of Product per Day
Pulp Mills	
Groundwood	250
Soda	300
Sulfate	-
Sulfite	310
Misc. Paper - no bleaching	440
" " - with bleaching	460
Paperboard	210
Strawboard	140

Sources and Quantity of Wastes

The chief sources of wastes in the pulp industry are the digester liquors. Other wastes are from barking, and chipping operations; screens, rifflers, knotters and thickeners; and bleach and bleach washes.

At paper mills most of the wastes are from the beaters, regulating and mixing boxes, screens, and paper machines. The average quantities of wastes which may be expected from pulp and paper mills are shown in Table P-4. Paper mill water consumption and fiber loss quantities represent conditions found prior to concentrated pollution control measures.

Table P-4 Average Waste Discharges per Ton of Product.

Product	Gallons of waste per ton of product daily
Pulp Mills	
Groundwood	5,000
Soda	85,000
Sulfate (Kraft)	64,000
Sulfite	60,000
Misc. Paper - no bleaching	39,000
" " - with bleaching	47,000
Paperboard	14,000
Strawboard	26,000
Deinking - old paper stock	83,000

Fiber losses in paper mills may vary from 0.1 to 20 percent, generally averaging around 3 percent. Where bleaching is done it has been found that unit waste volumes are larger but, due to the efficiency of rotary filters used as bleach washers and to the reuse of white water, the fiber losses are reduced. The bleaching operation removes additional organic solids from the pulp, resulting in an increased oxygen demand of such wastes.

Character of Wastes

Pulping Process Wastes

The character of the various wastes from pulping operations is as follows:

Sawing, Barking, and Chipping - Bark press and wood wash wastes contain suspended wood matter which, if discharged directly to the stream, may contribute turbidity and possible deposits.

Digester Liquors - These are the most objectionable wastes produced in any appreciable quantity in the pulping process. The black liquors contain intercellular substances of the wood and excess chemicals used. Sulfite digester liquor, for example, contains about 48 percent of the wood used, has a high immediate chemical oxygen demand due to the presence of such compounds as sulfur dioxide, has a high B.O.D., and contributes color. It may impart an acidic condition and introduce compounds ofa toxic character, such as lignin salts, which may be harmful to aquatic life. Sulfate digestion sometimes forms small quantities of mercaptans. These have a disagreeable odor and are reported to be toxic to fish life in concentrations of more than one part per million. In Michigan it is reported that from 10 to 15 percent of the sulfate black liquor is lost in the final washing of the pulp. Occasions are said to have arisen where the flesh of fish has become tainted due to absorption of these odors.

Wash waters - These are used following draining of the pulp in the blow pit and are generally dilute liquors of a character similar to the black liquors. Escaped fiber may also be present in this waste. Some plants store and reuse these waters as subsequent washes and pass them, when too concentrated for wash use, through the recovery process along with black liquor.

Screens, Rifflers, Knotters, and Thickeners - Coarse undisintegrated material, knots, granular impurities, and fiber make up this waste. Some of these substances may be recovered and reprocessed.

Bleach Wastes - These contain fine fiber and excess calcium hypochlorite bleach. Bleaching releases additional organic material from the pulp and adds to the oxygen loads of the wastes. The lime sludge formed, if discharged as waste, will add alkalinity and possibly calcareous deposits to the stream.

Recovery Process Wastes - Certain residual wastes remain even when recovery is practiced. These consist mostly of dumped sludges as well as leakages and spills of black liquors.

Paper Mill Wastes

In general, the bulk of the oxygen requirement for paper mill wastes comes from dissolved organic substances. Although fiber exerts a slow oxygen demand, its deposition in stream beds may prevent growth of normal vegetation. In addition, these deposits may rise to the surface during decomposition and cause nuisances. The character of the specific wastes in paper manufacturing is as follows:

Beater wastes - Water used to wash raw stock will discharge wastes containing dirt, fiber, and clay. Raw stock fiber loss may amount to 1 percent of the production while waste materials in reclaimed paper washes may be 25 percent of the weight of old paper treated.

Regulating and mixing box - The consistency of the pulp is regulated by diluting or dewatering,and wastes, or white water, from this source may carry lost fiber and filling materials. This results in turbidity and settlement effects in the stream, as well as additional oxygen requirements.

Screens - The removal of fiber clumps may be accompanied by refining and return to the system. Discharge to the stream adds to the depositing possibilities.

Paper machine - White waters containing fiber and filling materials are discharged from the vacuum rolls. These wastes may contain up to 45 percent of the clay used and 5 percent of the fiber produced.

Strawboard Wastes

The most concentrated and polluting waste in the manufacture of strawboard paper comes from the beaters where the straw is washed after digestion. It contains lime, dirt or silica, and organic matter. The machine waste, which also includes the felt wash, is less concentrated and contains mostly fiber.

Table P-5 shows typical analytical results and sewered population equivalents for pulp and paper mill wastes.

Table P-5 Sewered Population Equivalents and Typical Analytical Results.

Product	Sewered Population Equivalent		Typical Analytical Results	
	Biochemical Oxygen Demand	Suspended Solids	Biochemical Oxygen Demand	Suspended Solids
	Per Ton of Product		Parts per Million	
Pulp Mills				
Groundwood	16	-	645	-
Soda	460	6,100	110	1,720
Sulfate (Kraft)	390	-	123	-
Sulfite	1,330	-	443	-
Misc.paper-no bleach	26	520	19	452
" " with bleach	40	220	24	156
Paperboard	97	445	121	660
Strawboard	1,230	1,920	965	1,790
Deinking-used paper	1,250	-	300	-

Where bleaching is done the increase in equivalents is due to the additional organic matter released from the pulp by the bleach. Combination pulp and paper mills will, in general, have lower sewered population equivalents on a ton production basis than the pulp mills. This is due to differences in weight of final product caused by the addition of loading materials and to the use of purchased pulps for mixtures required in certain papers.

Pollution Effects

The principal effect of pulp and paper wastes is one of deoxygenation due to organic oxygen demand of the waste. Where fiber losses are high deposits are created. Color is also an objection. In general, wastes from pulping processes are more objectionable than wastes from paper machines.

Probably the greatest stream pollution problem in connection with pulp and paper mills is presented by the discharge of waste sulfite liquor. A large part of this waste is carbonaceous and suffers decomposition by bacterial action. The solids also create heavy sludge deposits, forming a mat over the stream bottom and smothering the aquatic plant life. Depletion of the dissolved oxygen will also affect fish life, causing either migration or death by suffocation. Experiments have shown that while sulfite waste liquor dilutions of 1 to 500 were irritating to fish, definite toxic effects occurred mainly in dilutions of 1 to 200 or less. However, since these wastes would probably deplete the dissolved oxygen in a stream below the critical amount necessary to sustain fish life before the limiting dilutions are encountered, the most significant characteristic from the pollution standpoint is the oxygen demand. Development of Sphaerotilus locally referred to as "slime" causing clogging of nets, screens, etc., is reported below one sulfite mill despite a high dilution of the waste.

Remedial Measures

The treatment of pulp and paper mill wastes and possible economical by-product recovery have been the object of much research. Some of the results have led to actual plant use. However, certain problems, particularly having to do with sulfite pulp and strawboard waste disposal have not been satisfactorily solved and continued research is needed.

Preparation of Wood for Pulping

Bark and sawdust at pulp mills may be recovered by screening, flotation, or sedimentation and then dried and incinerated for heat recovery. Bark chips may be leached and, after washing and grinding, be mixed with kraft paper to form laminated press board.

Soda and Sulfate Pulp

Soda and sulfate black liquors are processed for recovery of chemicals and heat. These liquors are evaporated, burned in a rotary furnace, leached, causticized with lime, diluted with raw black liquor, and stored for reuse in the digester. New lime is used to replace that lost and soda ash or salt cake is added for the soda or sulfate process, respectively. The two chief by-products of these recovery processes are carbon and calcium carbonate sludge. The carbon residue is activated or otherwise prepared and marketed under various trade names, important uses being as a decolorizing agent, lamp black adulterant, and in the case hardening of steel. Lime sludge from causticization is burned and either reused to causticize more liquor or is marketed as agricultural lime or whiting. At some plants the carbonate is used as a loading material. Black liquor wash waters from the blow pits are sometimes run through the above process when too concentrated for reuse as primary washes.

Sulfite Pulp

Sulfite black liquor has been the subject of extensive research aimed at accomplishing an economic recovery. One method for the treatment and recovery of waste sulfite liquor which has received much attention is the Howard process now in use at one mill. The method is essentially a three-stage precipitation process, using a caustic lime reagent. The screened raw liquor is mixed with sludge from the third settling tank, treated with lime, and settled. The effluent goes through secondary and tertiary precipitation and settling, using lime in each case. Primary sludge is recovered to make cooking acid; secondary sludge is vacuum filtered, the cake being used for fuel and the filtrate returned to the process; and the tertiary sludge is mixed with incoming raw liquor prior to primary reaction and settling, the filtrate being run through a heat exchanger to recover heat for use in heating water for bleaching. It is claimed that the liquors processed contain 90 to 95 percent of the organic matter dissolved in the digesters and that the total B.C.D. reduction will be over 80 percent. Studies of the actual installation at a Wisconsin paper mill have shown a B.C.D. reudction of 45 percent to be the best obtainable from the process. The results obtained depended to some extent on the types of wood and the cooking procedures used.

The Paulson process involves evaporation and utilization of sulfite liquor as a fuel. A double effect evaporator is used and heat is recovered for preheating the sulfite liquor and for cooking in the digesters. The effluent syrup will contain 50 to 55 percent solids and can be burned in liquid form under the boilers. No results of actual performance on a plant scale are available as no commercial installations are known to exist. However, the process has been reviewed by several investigators and all have agreed that it is feasible and practical.

By-products suggested by other studies include adhesives, fertilizers, alcohol, tanning liquor, dye bases, road binder, binder for briquetting hard coal dust, and core binder. The use of these various processes is at present limited by the expense of treatment and a limited market for the absorption of the by-products.

In experiments on the purification of mixtures of sewage and sulfite waste liquors by the activated sludge method, satisfactory results were obtained with sewages containing up to 6 percent of Howard process effluent and up to 10 percent of raw calcium-base sulfite liquor. Higher percentages produced sludges too heavy to be kept in suspension by normal aeration, due to the precipitation of calcium carbonate. A magnesium-base sulfite liquor produced bulking sludges. The importance of adding nitrogen and phosphorous in assimilable form to dilution waters used for determining the B.O.D. of mixtures containing high proportions of sulfite wastes was shown. It is reported that failure to add these necessary nutrients accounts for the claims of high B.O.D. removals of the Howard process.

The use of save-all devices and closed water systems in pulp mills is in general governed by the economic value of the practice to the manufacturer. Under these circumstances treatment may be practiced up to the point of maximum economic recovery. In many cases this may be far from satisfactory from a pollution elimination standpoint.

Paper and Board Mills

A review of actual practice in the treatment and disposal of paper and board mill wastes shows the methods of correction, in general, to be as follows:

Save-Alls, Recirculation - Screens, vacuum filters, flotation and sedimentation devices, and recirculation with or without save-all clarification are common for machine wastes. At three Pennsylvania board mills save-all with recirculation in a partially closed system effected B.O.D. reductions varying from 39 to 85 percent while at three other mills having closed systems and sedimentation of weekly or other intermittent wastes gave B.O.D. reductions of 90 percent. For other plants using save-alls and a partially closed system, reductions were reported as 64 percent at a fine paper mill, 50 percent at a tissue mill, and 79 percent for a towel mill. In general, these practices can be applied with high overall efficiencies to board mills, where suspended matter can ordinarily be returned to the product, and to paper mills working on clean raw material such as wood pulp, paper shavings, and clean rag stock or pulp. Costs of recirculation systems are subject to considerable variation but a figure in the order of magnitude of $5,000 per machine is typical. Savings in water and material will result. In the case of plants having color change complications recirculation and recovery as commonly applied effect a machine waste correction only.

Chemical precipitation - This method has been applied to the various wastes. A Michigan mill making tarboard automobile strips on a wet machine and boxboard, wrappers, asbestos board, and similar products on a dry machine treats these wastes separately and returns the sludge to the respective processes. B.O.D. reductions of about 64 percent were obtained in each case. At an Indiana mill manufacturing grease proof, glassine, and manifold paper from sulfite pulp treats all wastes with alum in the first of three ponds in series. The sludge is dried on beds and the effluent from the third pond is recirculated to the process. Estimated costs of chemical precipitation are shown on Table P-6.

Table P-6 Estimated Cost of Chemical Precipitation

Mill Production Tons per day		Waste Flow M.G.D.	Total Installation Cost	Daily Operation and Maintenance
Paper	Board			
25	50	0.5	$30,000	$19
50	100	1.0	45,000	33
100	200	2.0	70,000	60
150	300	5.0	155,000	143

Ponding - An Ohio mill producing paperboard from wood pulp, paper shavings, and old newspapers discharges its beater wastes to a seepage pond. Another Ohio mill with similar raw materials and products provides ponding for 10 percent of the machine wastes and multiple sedimentation for the remaining 90 percent. About 80 percent of the waste water is recirculated. A large Pennsylvania pulp and paper mill has provided for its deinking wastes a reservoir having a capacity 60 times the daily discharge of these wastes plus wash waters from the used paper department. The pond effluent is aerated in cascading 1.4 miles down a steep channel to the river. The overall reduction in B.O.D. is about 77 percent.

Filtration - No installations of this type are known to be in present use. Two Massachusetts paper mills formerly used this method of treatment but it was later discontinued. One of the mills produced manila and other papers from rope, bagging, and wood pulp. Machine wastes were recirculated to the washers, while cinder filters received all the settled washer waste and as much of the settled beater waste as they would take. Rotary liquor was discharged either on the drying sludge or on to the cinder filters, resulting in a lowering of their efficiency. The other mill produced heavy paper boxes, shipping cases, cartridge cases, and similar items from cotton and hemp stock. Machine wastes were settled with alum by fill and draw operation, with a return of sludge to the process and the discharge of the effluent to the stream. Boiler liquors were discharged to waste land while washer wastes were treated by plain sedimentation and sand filtration.

Bibliography

(1) Cole, Arch E.; Sewage Works Journal, V. 7, March 1935.

(2) Connecticut, State of; Unpublished Data.

(3) Curran, C. E.; Reprint from Proc. No. Amer. Wildlife Conference, February 3-7, 1936.

(4) Eldridge, E.F.; Bulletin 82, Michigan Eng. Exp. Sta., September 1938.

(5) Fales, A.L.; Ind. and Eng. Chemistry, V. 21, March 1929.

(6) Gleeson, G. F., and Merryfield, F.; Bulletin Series No. 7, Eng. Exp. Sta., Oregon State Agricultural College, May 1936.

(7) Holderby, J. M.; Paper Trade Journal, April 6,1933.

(8) Hommon, H. B.; U. S. Public Health Service Bulletin 97, October 1918.

(9) Howard, Guy C.; Paper Trade Journal, July 2, 1936.

(10) Kimball, H. S.; Paper Trade Journal, March 23,1933.

(11) Louisiana Conservation Review, Summer 1941.

(12) Main State Sanitary Water Board; Bulletin No.1, 1942.

(13) Merryfield, F.; Civil Engineering, V. 6, June 1936.

(14) Michigan Stream Control Commission, Second Biennial Report, 1933-34.

(15) Mohlman, F. W.; Sanitary District of Chicago, Unpublished Data.

(16) Paulson P. A.; Private Communication.

(17) Process Industries, Flow Sheets and Data Book, Compiled by Chem. and Met. Eng'g.

(18) Sawyer, C. N.; Ind. and Eng. Chem., V. 32, p. 1469, (1940).

(19) Scott, G. R.; Tennessee Valley Authority, Unpublished Report.

(20) Spence, G. K.; Proc. A.S.C.E., V.53, September 1927.

(21) Thorp, F. H.; Outlines of Industrial Chemistry.

(22) U. S. Public Health Service, Unpublished Data.

(23) Warrick L. F.; Civil Engineering, V. 3, September 193

(24) Warrick, L. F.; Joint Report, Wisconsin State Committee on Water Pollution, State Board of Health and Green Bay Metropolitan Sewerage District, 1938-1939.

(25) Warrick, L. F.; Private Communication.

(26) Warrick, L. F.; and McKee, J. F.; Paper Trade Journal, December 8, 1938.

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

I-8
Rev.8-39

PULP AND PAPER MILL WASTES (Not an Actual Plant)

Plant Burden Pulp Co. State Ohio Ref.No. CP-217

City Fair City County Weaver Main Watershed Chase River

Address 600 Main Street Sub-watershed Perry Creek

Informant A. B. Chester Title Gen. Super. Principal Product Pulp

Plant Operation:	Hours per Week	Days per year	Plant Employees
Average	144	300	200
Maximum			

Seasonal variation None

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking				
Industrial	City	3,500,000		None
Cooling	Creek	No est.		"

RAW MATERIALS:- Wood 140 cords spruce/day Soda pulp

Sulphite pulp Old paper

Groundwood pulp Straw

Paper shavings Rags

Chemicals:- ~~Clay~~ Sulfur 17,500 lbs./day ~~Talc~~ Limestone 21,000 lbs./day

Alum Size Soda ash

Caustic soda Bleaching Powd. 28,000 lbs./d Dyes

PRODUCTS:- Capacity in T/day 80 T./day Normal operation 70 T./day

Bleached sulfite pulp, air dried, 10% moisture

WASTES:- Quantity 3.5 M. G. D. How estimated Meter records

Character Washings - 2 m.g.d.; process - 1.5 m.g.d.

Disposal other than water carried Bark and sawdust burned

Dump of stock chest when change colors

Possible spills None reported

Segregation of Strong Wastes

Difficulties

Treatment Fine screen save-all Recovery practices

Analyses:- Number None Date By whom

Appearance Turbid

OUTLET:- Where to Perry Creek

Description:	Size and shape	Material	Location	Elevation
1.	30" circ.	Concrete		
2.				
3.				

Gaging possibilities Good. Manhole in sewer

Conditions below outlet: Color Dark gray

Turbidity Deposits Below Outlet

SANITARY SEWAGE: Disposal City sewer Persons tributary 200

REMARKS Ashes used for fill.

Survey by D. E. Fowler Date 5-17-39

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES (Not an Actual Plant)

River Mileage Index No. CP-217.5

Type of Plant **Pulp Mill** State **Ohio**

Name of Plant **Burden Pulp Co.**

Municipality **Fair City** Main Watershed **Chase River**

County **Weaver** Subwatershed **Perry Creek**

Address **600 Main Street**

Source of Information **A. B. Chester, Gen. Sup't.**

Plant Operation:-

100 hours/week - 300 days/year.
Average 200 plant employees.

Seasonal Variation:-

None

(Survey report continued on next page)

Survey by **D. E. Fowler** Date **5-17-39**

Sewered Population Equivalent Computation:-

Factors used **per ton of pulp produced daily.**

B.O.D. **1,330** Suspended solids **not available**

Sewered population equivalent* based on B.O.D. **93,000**

Sewered population equivalent* based on suspended solids **-**

Remarks:

P. E. based upon normal daily production.

Computation by: **G. H. Innes** Date **1/10/40.** Cincinnati Office

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant of the factors used becomes available.
*Rounded to nearest two significant figures.

Burden Pulp Co.,
Fair City, Ohio.

Water Supply -

	Average	Source	Treatment
Drinking & Industrial	3.5 M.G.D.	City	None
Cooling	No est.	Creek	None

Raw Materials - Per day.

Spruce wood	- 140 cords
Sulfur -	17,500 pounds
Limestone	21,000 pounds
Bleaching Powder	28,000 pounds

Products - Sulfite pulp.
Production capacity- 80 tons/day.
Normal production - 70 tons/day.

Average - 3.5 M.G.D. plus cooling water. 2.0 M.G.D. washings and 1.5 M.G.D. of process wastes. Estimates based upon meter records. Wastes are discharged through a fine screen save-all. Bark and sawdust are burned and the ashes used for fill. The plant effluent had a turbid appearance.

No analyses were available.

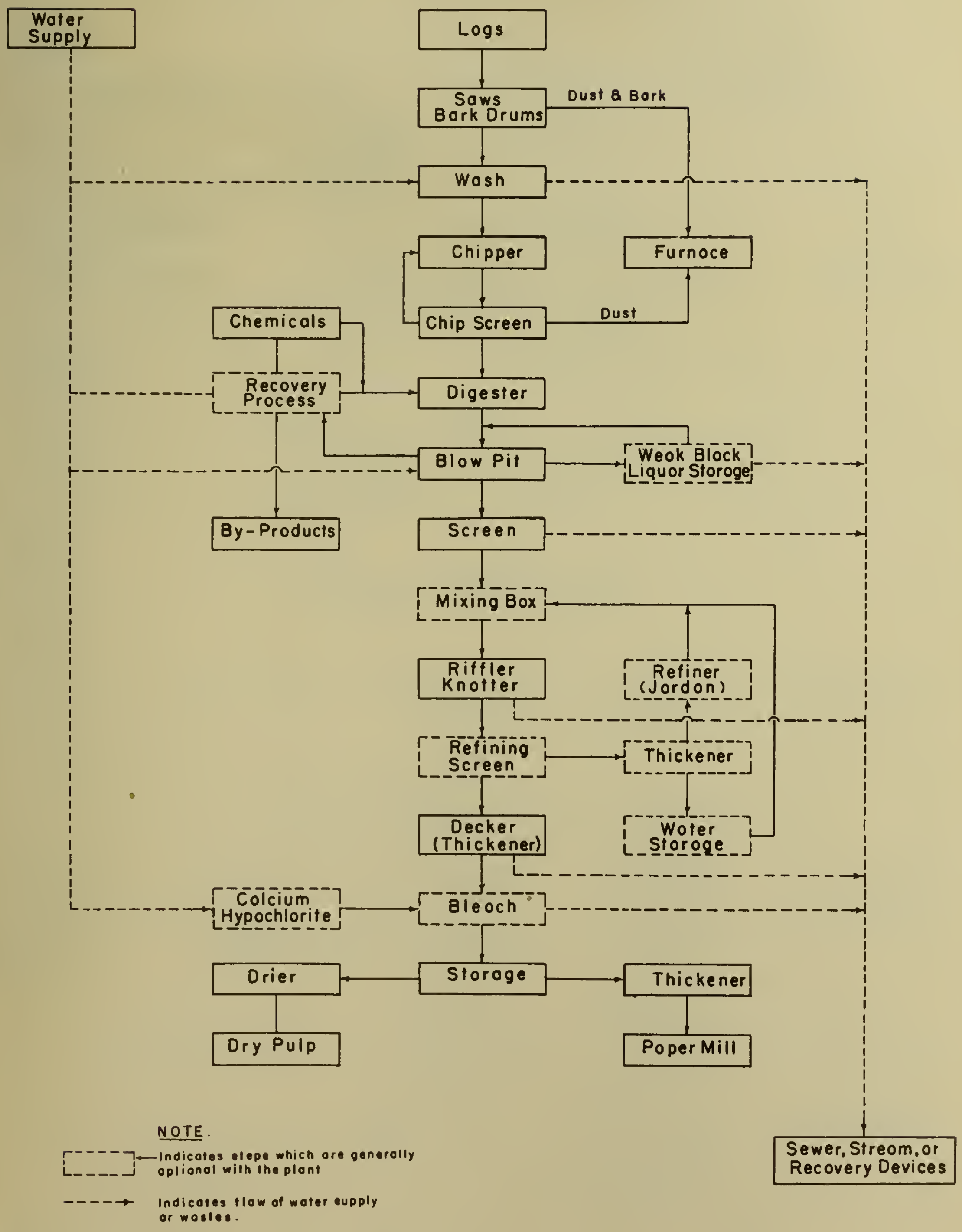
Outlet - One 30" circular concrete sewer discharges all wastes, except sanitary, to Perry Creek.

The water below the outlet had a dark gray color and some deposits were visible on the stream bank.

Sanitary Sewage - Discharged to city sewer. 200 persons tributary.

FLOW DIAGRAM

PULP MILL



NOTE.

Indicates steps which are generally optional with the plant

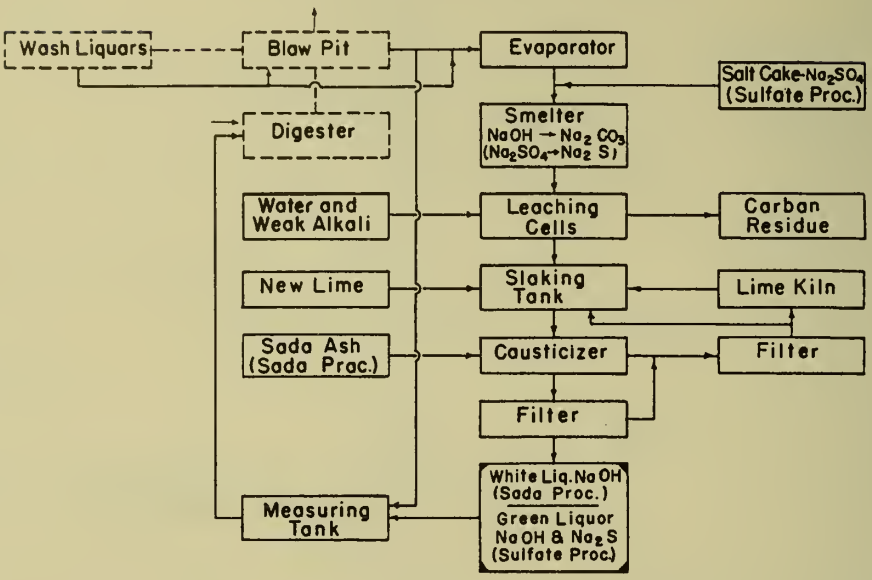
Indicates flow of water supply or wastes.

OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

FLOW DIAGRAM

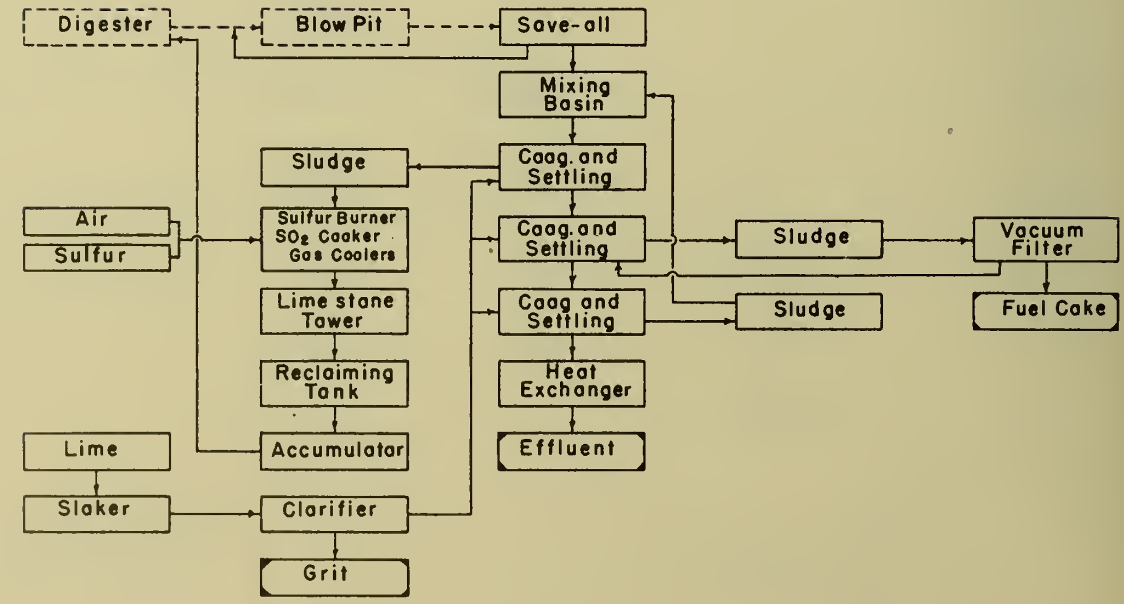
PULP MILL BLACK LIQUOR RECOVERY PROCESSES

SODA & SULFATE (KRAFT) LIQUORS


Wash Liquors
Blow Pit
Evaporator
Salt Cake-Na_2SO_4 (Sulfate Proc.)
Digester
Smelter $NaOH \rightarrow Na_2CO_3$ ($Na_2SO_4 \rightarrow Na_2S$)
Water and Weak Alkali
Leaching Cells
Carbon Residue
New Lime
Slaking Tank
Lime Kiln
Soda Ash (Soda Proc.)
Causticizer
Filter
Filter
Measuring Tank
White Liq. NaOH (Soda Proc.) Green Liquor NaOH & Na_2S (Sulfate Proc.)

SULFITE LIQUOR

(HOWARD PROCESS)



OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

I-8
Rev.8-39

PULP AND PAPER MILL WASTES (Not an Actual Plant)

Plant Ordon Paper Co. State Ohio Ref.No. MR-21.7

City Jonesville County Whipple Main Watershed Midway River

Address 2300 Broadway Sub-watershed Rangoon Creek

Informant A. B. Clark Title Plant Super. Principal Product Paper

Plant Operation:	Hours per Week	Days per year	Plant Employees
Average	144	300	375
Maximum			

Seasonal variation Very Little

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking				
Industrial	Wells	7,000,000	8,000,000	Boiler water soft.
Cooling	Creek	7,000,000	9,000,000	None

RAW MATERIALS:- Wood Soda pulp 7.1 T./day

Sulfate ~~Sulphite~~ pulp 125 T./day Sulfite Pulp ~~Old paper~~ 105 T./day

Groundwood pulp 1.4 T./day. Straw

Paper shavings 20.6 T./day. Rags (Pulp) 2.1 T./day

Chemicals:- Clay 2.5 T./day Talc 0.2 T./day

Alum 4.5 T. /day ~~Size~~ Rosin 1.7 T./day Soda ash 1.3 T./day

Caustic soda 0.2 T./day Bleach 1.1 T./day Dyes 104 T./day

PRODUCTS:- Capacity in T/day 275 Normal operation 250

Specialty paper products

WASTES:- Quantity 14 M.G.D. How estimated Pump capacities

Character Cooling - 7 m.g.d.; washings - 3.5 m.g.d.; process - 3.5 m.g.d.

Disposal other than water carried None

Dump of stock chest when change colors

Possible spills Occasional from chests running over

Segregation of Strong Wastes Screen felt shower and press wastes to save-all

Difficulties None reported

Treatment Save-all Recovery practices

Analyses:- Number None Date By whom

Appearance White

OUTLET:- Where to Rangoon Creek

Description:	Size and shape	Material	Location	Elevation
1.	Several outlets ranging			
2.	from 10" to 30"			
3.				

Gaging possibilities Poor - several outlets

Conditions below outlet: Color White

Turbidity High Deposits Below outlets

SANITARY SEWAGE: Disposal City Sewer Persons tributary 375

REMARKS Little recirculation - frequent color changes

Survey by D. E. Fellows Date 7-14-40

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI,OHIO

INDUSTRIAL WASTES (Not an Actual Plant)

River Mileage Index No. MR-21.7

Type of Plant **Paper Mill** State **Ohio**

Name of Plant **Ordon Paper Co.**

Municipality **Jonesville** Main Watershed **Midway River**

County **Whipple** Subwatershed **Rangoon Creek**

Address **2300 Broadway**

Source of Information **A. B. Clarke, Plant Superintendent**

Plant Operation:-

144 hours/week - 300 days/year
Average 375 plant employees

Seasonal Variation:-

Very little

(Survey report continued on next page)

Survey by **D. E. Fellows** Date **7-14-40**

Sewered Population Equivalent Computation:-

Factors used **per ton paper produced daily.**

B.O.D. **40** Suspended solids **217**

Sewered population equivalent* based on B.O.D. **10,000**

Sewered population equivalent* based on suspended solids **54,000**

Remarks:

P. E. based upon normal daily production.

Computation by: **G.H.Inman** Date **12/9/40.** Cincinnati Office.

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
* Rounded to nearest two significant figures.

Ordon Paper Co.,
Jonesville, Ohio.

Water Supply

	Average	Maximum	Source	Treatment
Drinking & Industrial	7 M.G.D.	8 M.G.D.	Wells	Boiler water softened
Cooling	7 "	9 "	Creek	None

Raw Materials - Tons/day

Soda Pulp	- 7.1	Talc	- 0.2
Sulfite Pulp	- 105	Alum	- 4.5
Groundwood Pulp	1.4	Rosin	- 1.7
Sulfate Pulp	125	Soda Ash	- 1.3
Paper Shavings	- 20.6	Caustic Soda	- 0.2
Rag Pulp	- 2.1	Bleach	- 1.1
Clay	- 2.5	Dyes	104

Products - Specialty paper products.
Production capacity - 275 Tons/day.
Normal production - 250 Tons/day.

Wastes - Average 14 M.G.D. 7 M.G.D. cooling water, 3.5 M.G.D. washings, 3.5 M.G.D. process wastes. Estimates based upon capacities and operating schedules of the pumps. No disposal other than water carried.

Spills occur occasionally from chests running over. There is no treatment except a save-all on the screen-felt shower and press wastes.

No analyses were available.

Wastes have a white appearance and contain some suspended matter.

Outlets - There are several separate outlets varying in size from 10" to 30" and all discharging to Rangoon Creek. Gaging would be difficult because of the large number of outlets.

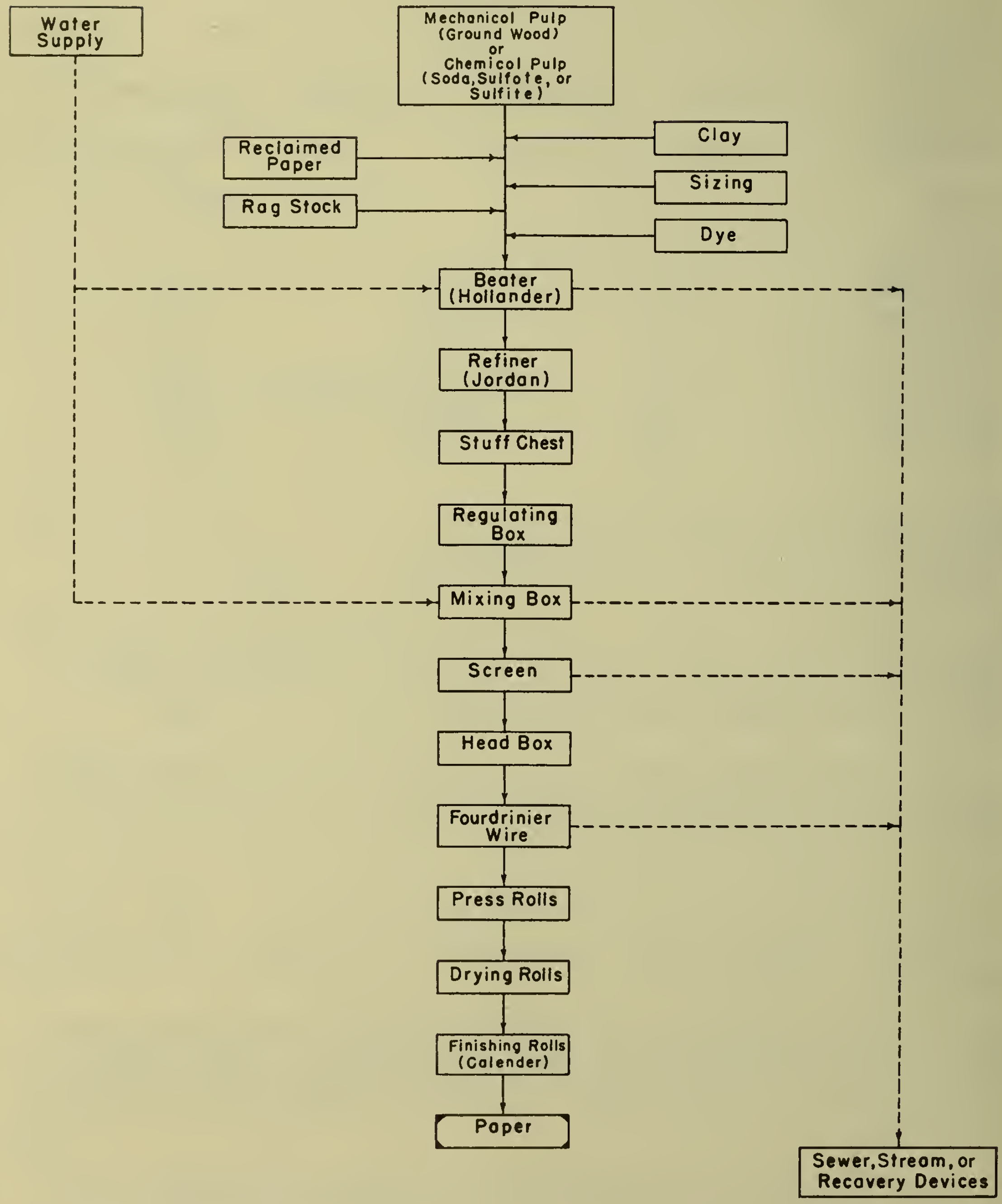
An inspection of conditions below the outlet showed a white color, high turbidity, and some deposits.

Sanitary Sewage - Discharged to city sewers. 375 persons tributary.

Remarks - Very little recirculation is practiced because of the frequent color changes.

FLOW DIAGRAM

PAPER MILL



OHIO RIVER POLLUTION SURVEY
U.S. PUBLIC HEALTH SERVICE
1942

OHIO RIVER POLLUTION SURVEY

TANNERY

An Industrial Waste Guide to the Tannery Industry

APPENDIX "XI" OF SUPPLEMENT "D"
to the
Final Report
to the
Ohio River Committee

1798

Federal Security Agency
U. S. PUBLIC HEALTH SERVICE
Office of Stream Sanitation
Cincinnati, Ohio
1942

Contents

Page

Abstract T-1
Description of Process T-2
Raw Materials and Products T-3
Sources of Wastes. T-4
Quantity and Character of Wastes T-5
Pollution Effects. T-9
Remedial Measures. T-9
Bibliography T-15
Note Taking Form T-17
Inspection Report. T-18
Flow Diagram T-21

List of Tables

T-1 Approximate Quantity and Character of Wastes from Various Steps in Vegetable Tanning Process (Heavy Leather). T-7

Abstract

A vegetable tannery engaged in converting raw hides into leather produces wastes principally from the processes of clearing, unhairing and fleshing the hides, from the tanning process, and from bleaching of the tanned leather. The wastes contain hide substance, hair, fats, and the various chemicals used in the process principally lime, sulfides, tannins, soda ash, and sulfuric acid. The combined wastes are usually highly alkaline although the wastes from the tan yard and part of the bleach wastes are acid. The wastes are particularly high in suspended solids because of the presence of large amounts of undissolved lime. Spent tan liquor and the soda bleach wastes are strongly colored and this color is very difficult to remove.

One hundred pounds of green salted hide, as received at the tannery, will produce about 68 pounds of finished leather. Ohio Basin tanneries employ an average of about seven men per 100 pounds of hide processed per day. The combined wastes from the tannery amount to about 800 gallons per 100 pounds of hide and contain about 2,400 p.p.m. of suspended solids and 1,200 p.p.m. of B.O.D. The sewered population equivalents of vegetable tanning wastes are about 48 (B.O.D.) and 80 (Suspended Solids) per 100 pounds of hide per day. All of these figures are subject to wide variations.

The only treatment method in common use is mixing of acid and alkaline wastes followed by sedimentation. Various secondary treatment devices have proven successful in experimental plants but the high cost of such treatments have prevented their wide use. Chemical precipitation using various chemicals has been studied and found effective but expensive. The sludge disposal problem is difficult. From 7 to 10 percent of the waste volume is sludge. Drying beds or lagoons are the standard methods of dewatering the sludge. Vacuum filters and centrifuges have not yet proved satisfactory. The sludge has some value as a fertilizer.

Wastes from chrome tanneries are considerably weaker than those from vegetable tanneries. Limited data indicate sewered population equivalents to be about 24 (B.O.D.) and 40 (Suspended Solids).

Description of Process

Raw hides and skins are made into leather by tanning. The two principal processes in use are vegetable tanning and chrome tanning. In either case the raw or salted hides delivered to the tannery are cleaned and the hair and flesh removed prior to the actual tanning process. This is done in the beam house and, in general, the methods used are the same regardless of the method of tanning although they vary considerably in detail from plant to plant, depending largely on the type of skin or hide being handled and the product desired. In the tan yard the prepared skins are immersed in the tanning agent, either an extract of the bark, wood or nuts from various trees or a solution of chromium salts. After tanning, the leather is dried and finished in the finishing department.

Most of the tanneries operating in the Ohio Basin produce "heavy" leather; i.e. sole and belting leather and use the vegetable tanning process. The processes described here are typical of a sole leather tannery.

Beam House

(a) Soaking - Salted cow and steer hides are soaked in vats of water for one or two days to clean and soften them.

(b) Liming - The hides are placed in vats containing solutions of lime and sodium sulfide which loosen the hair by dissolving the outer hide layers. This requires from three to seven days.

(c) Warm pool - (optional) The hide is soaked in warm water for about one hour.

(d) Unhairing - White hair is removed by hand because of its higher market value and the remainder is removed by machine.

(e) Fleshing - The flesh attached to the inner surface of the hide is removed roughly by hand and machine.

(f) Wash wheel - The hides are placed in revolving drum where they are tumbled about while clean water carries away the lime.

(g) Deliming - The lime remaining in the washed hide is removed by either water alone, or a bath containing a small amount of acid.

(h) Bating - The hide is placed in a solution containing proteolytic enzymes buffered with ammonium salts.

Tan Yard

(a) Rockers - The hides are suspended from rocker frames (dipping motion) in vats of vegetable tan liquor and are exposed to progressively stronger liquors.

(b) Layers - From the head rocker the hides pass to the layer vats containing the heavy tanning liquor in which tanning is completed. The length of time required for tanning varies considerably but the average is about 70 days. There is a tendency toward shortening the time required.

Finishing Department

(a) Bleaching - The tanned hide is passed to the scrub house where it is bleached in a sodium carbonate solution followed by a bath in dilute sulfuric acid to neutralize the excess soda and finally a dip in water.

(b) Other finishing - Processes such as impregnation with oils, concentrated tanning liquors, sugar, salt, etc., are used depending on the type of product desired.

In chrome tanning the hides from the beam house are pickled in a bath of salt and acid for about one hour, then tanned in a mixture made by reducing sodium bichromate and sulfuric acid with glucose. This may take from several hours to several days. Treatment with alkali, such as sodium bicarbonate, usually follows to neutralize the excess acid. Chrome tanned leather is not bleached. Some tanneries use both processes.

Raw Materials and Products

Salted cow and steer hides are commonly used for "heavy" leather. These hides vary considerably in weight. At the tanneries surveyed in connection with the Ohio River Pollution Survey the reported average weight varied from 35 to 65 pounds and the over-all average was about 52 pounds. These same plants reported from 62 to 75 pounds of leather per 100 pounds of salted hide with an over-all average of 68 pounds.

Vegetable tan liquors are composed chiefly of infusions of chestnut wood, quebracho wood, and hemlock or oak bark. An increasing number of tanneries buy tanning extract although many still make their own extract from tan bark for at least a part of their needs.

The principal chemicals used are lime and sodium sulfide for hair loosening and soda ash and sulfuric acid for bleaching. The average amounts of these chemicals used at plants in the Ohio Basin where such data were available were:

Lime	10	pounds	per	100	pounds	of	hide
Sodium sulfide	0.25	"	"	"	"	"	"
Soda ash	0.75	"	"	"	"	"	"
Sulfuric acid	2	"	"	"	"	"	"

These amounts of lime and sulfuric acid are said to be representative of general practice but the amounts of sodium sulfide and soda ash are said to be only about half of the amounts ordinarily used.

Lactic acid is used in some tanneries in deliming and, if the hides are bated, ammonium salts and proteolytic enzymes are used. Various dehairing agents are used with lime in different tanneries. The more important ones are sodium sulfhydrate, dimethylamine, and arsenic sulfide.

The number of employees per 100 pounds of hide processed per day varied from about four to fifteen in 22 vegetable tanneries in the Ohio Basin. The average was about seven employees per 100 pounds of hide per day. In general, the larger plants had fewer employees per unit of product than the smaller ones.

Sources of Wastes

Beam House

- Soak water
- Lime vat liquors
- Warm water pool liquors
- Unhairing machine water
- Hair washing water

Fleshing machine water
Wash wheel water
Deliming process water

Tan Yard

Spent tan liquor
Vat rinses, leather rinses, leakage

Finishing Department

Bleach liquor

Quantity and Character of Wastes

The amount of waste produced by tanneries has been found to vary from about 300 to 1,700 gallons per 100 pounds of hide processed. Howalt and Cavett reported that the waste flow of 617 gallons per 100 pounds of hide at the Instanter, Pa., tannery was about the average of 51 plants in 10 states. Data on 18 Pennsylvania vegetable tanneries show variations of from 300 to 1,300 gallons with an average of 730 gallons per 100 pounds of hide. Twenty-one tanneries in the Ohio Basin have waste flows of from 400 to 1,700 gallons per 100 pounds of hide and an average of 800 gallons. From 700 to 800 gallons per 100 pounds of hide seems to be a fairly representative figure for the average vegetable tannery, but there is ample evidence that, if necessary, tanneries can reduce their waste flows considerably below these average amounts without interfering with the quality of the product.

Several hundred analyses of the combined wastes from various tanneries in Pennsylvania, West Virginia, Michigan, Tennessee, North Carolina, and Kentucky indicate that the following is fairly representative of the character of the combined wastes from a vegetable tannery.

Waste Volume	800	gallons per 100 pounds of hide
Total Solids	7,200	p.p.m.
Volatile Solids	3,600	p.p.m.
Suspended Solids	2,400	p.p.m.
B.O.D.(5-day 20°C)	1,200	p.p.m.
Color (A.P.H.A.)	3,500	p.p.m.
pH	11	

Anthrax spores may be present in the wastes and in the recovered products such as fertilizer.

The character of the wastes from individual steps in the process are as follows:

Beam House Wastes

Soak waters, discharged intermittently, contain dirt, dung, blood and other soluble proteins, salt, hair and sometimes degradation products as major impurities. They have a dark, dirty, olive green color.

Lime vat effluents, discharged intermittently, contain dirt, hair, dissolved putrescible organic materials and lime. They have a bluish milky appearance.

Warm pool wastes, discharged intermittently, are similar in character and appearance to the lime vat discharged but are much weaker.

Unhairing machine wastes are discharged continuously, contain lime and fine hair, and are slightly turbid.

Hair washes are discharged continuously and are similar to unhairing machine wastes but somewhat weaker.

Fleshing machine wastes are continuous, contain small pieces of flesh and fat, and are highly putrescible.

Deliming wastes are discharged continuously, contain small amounts of lime and hide substance, are slightly turbid. If bating is done, the bate liquors are discharged intermittently.

Tan Yard Wastes

Spent tan liquor from the tail rockers, discharged intermittently, is the worst single waste as regards color, solids and B.O.D. It is reddish brown in color and is acid.

Rinse liquors sometimes used to wash hides at this point in the process are similar in character to spent tan liquor. These wastes are often returned to the process and are not discharged.

Finishing Department Wastes

Bleach wastes, discharged intermittently, contain spent soda and acid solutions, and rinse water which is also acid. It is usually colored.

Other finishing processes ordinarily do not produce wastes.

The wastes from the beam house are alkaline while the tan yard and bleach wastes are acid.

Table T-1 shows the approximate amounts and representative analyses of the individual effluents. Both the amount and character of the wastes vary widely from plant to plant.

Table T-1 Approximate Quantity and Character of Wastes from Various Steps in Vegetable Tanning Process (Heavy Leather)

Waste	Volume gal./100# hide/day	Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. 5-day p.p.m.	Percent of Total Solids	Percent of B.O.D.
Soaks*	80	12,000	1,200	600	17	5
Limes*	40	27,000	10,000	2,400	19	10
Warm Water*	50	10,500	3,500	1,000	9	5
Unhair	25	2,500	1,500	400	1	1
Hair Wash	40	2,000	1,200	200	1	1
Fleshing	35	3,500	2,600	800	2	3
Wash Wheel	200	1,600	450	700	6	15
Float Box	30	300	150	25	0	0
Green Stock	210	400	100	3	1	0
Spent Tan*	50	27,000	1,500	10,000	23	52
Bleaches*	40	30,000	1,200	2,000	21	8

* Intermittent discharges.

This table shows that the intermittent discharges which represent about one-third of the total waste volume contain almost 90 percent of the total solids and 80 percent of the B.O.D. of the combined wastes. The figures shown in Table T-1 for suspended solids cannot be used to determine the suspended solids content of the combined wastes since, upon mixing, some of the dissolved or colloidal solids in the individual wastes are precipitated. Many plants use a slush wheel as the first beam house process to clean the hides of gross filth before soaking. Bating is the last beam house process. Insufficient data prevent including representative quantities and analyses of the wastes.

Available data indicate the sewered population equivalent of combined vegetable tannery wastes to be about 48 per 100 pounds of hide processed on a basis of B.O.D. and about 80 per 100 pounds of hide on a basis of suspended solids. The beam house contributes about 89 percent of the waste volume and 40 percent of the B.O.D. The spent tan liquor constitutes about 6 percent of the volume and 52 percent of the B.O.D. and the bleaches about 5 percent of the volume and 8 percent of the B.O.D.

Data on chrome tanneries are somewhat less complete. Studies at the tannery testing station of the Sanitary District of Chicago in 1920-22 showed a population equivalent of about 22 per 100 pounds of hide based on B.O.D. and 34 based on suspended solids. The waste flow was about 845 gallons per 100 pounds of hide. More recent studies at a Waukegan, Illinois, chrome tannery indicated population equivalents of about 36 and 57 based on B.O.D. and suspended solids respectively. The average waste flow was 1,410 gallons per 100 pounds of hide and included an appreciable amount of infiltration. These studies showed that about 95 percent of the B.O.D., 91 percent of the total solids and 85 percent of the suspended solids came from the beam house wastes. At eighteen Chicago chrome tanneries sampled during 1936 B.O.D.'s varied from 300 to 3,000 p.p.m. with a weighted average of 930 p.p.m. and suspended solids varied from 500 to 3,300 p.p.m. with a weighted average of 1,310 p.p.m. No production figures are available with which these analyses can be correlated.

Assuming the beam house wastes from a chrome tannery to be the same as those from vegetable tanneries, the population equivalent based on B.O.D. should be about one-half as great for the chrome tannery as for the vegetable tannery. Actually, the beam house wastes may differ appreciably since the chrome process is used largely in making the lighter types of leather. No data are available to indicate the effect of these variations on the strength and amount of wastes. Suspended solids seem to be higher than the B.O.D. in most instances although at seven of the Chicago tanneries the situation was reversed. Sewered population equivalents of 24 (B.O.D.) and 40 (Suspended Solids) seem reasonable.

Pollution Effects

Tannery wastes exert a deoxygenating effect on the receiving stream. In addition, the large amounts of suspended solids often cause sludge banks in the stream which continuously deplete the dissolved oxygen in the stream and cause obnoxious odors. The color of vegetable tanning liquors is very strong and persistent. The liquor reacts with iron to form an ink-like substance which may be noticeable for many miles downstream. The intermittent discharge of the stronger wastes accentuates the pollution problem.

Untreated tannery wastes have caused considerable difficulty in municipal sewers by the deposition of suspended solids and the formation of calcium carbonate scale on the sewers. The caustic alkalinity in the wastes may also damage biological processes of sewage treatment if the tannery wastes constitute an excessively large part of the waste flow. Chrome salts from chrome tanneries may be toxic to the organisms necessary for sludge digestion.

There is relatively little danger of anthrax being present in native hides and skins since the disease is fairly well under control in this country. It is standard practice to disinfect all suspected hides at the tannery before processing.

Remedial Measures

Hair, fleshings, and hide trimmings are commonly collected and sold. The hair is washed, dried, and sold for use in the manufacture of rug pads, plaster binders, etc. The fleshings and trimmings are used in making glue. The fleshings may also be processed to obtain oil and grease. Leather trimmings are used in making artificial leather.

Lime sludge which settles to the bottom of the liming vats contains dirt, hair and organic matter. When discharging the wastes from the lime vats, this sludge may be allowed to remain in the vats or the entire contents may be mixed well and discharged. The sludge can be shoveled out after the tank has been drained and used as fertilizer or for liming fleshings. If discharged with the rest of the lime liquor, it adds greatly to the suspended solid load of the wastes and to their causticity.

Spent tan liquors may be condensed for reuse as a tanning agent or evaporated and the residue sold as boiler compound. Its use as a road material or a foundry core binder has been suggested. Spent tan bark is commonly burned. Where freight rates permit, it is used in the manufacture of white lead. It may also be used in making paperboard. Constant improvements in the tanning process promise to reduce to an important degree the amount of spent tan liquors discharged. Considerable progress has been made in this direction in recent years.

The use of dimethylamine or similar products in place of sodium sulfide as an aid in unhairing helps to reduce the B.O.D. of the wastes and eliminates a considerable part of the sulfides. Although the cost of dimethylamine is now greater than that of other depilatories, it has certain desirable qualities which may lead to its wider use with a consequent reduction in the strength of the wastes.

Sedimentation of either the combined wastes or of the stronger wastes is the only method of tannery waste treatment in common use today. Numerous studies of tannery waste treatment have been made in this country, particularly by the pollution abatement authorities of Pennsylvania, Massachusetts and Michigan, in cooperation with industrial groups and by the Sanitary District of Chicago in connection with the design of its treatment plants. The problem has also been widely studied abroad with results similar to those obtained in this country.

Primary Treatment

Mixing of the wastes and sedimentation has been found, in experimental plants, to remove about 70 to 80 percent of the suspended solids and about 40-50 percent of the B.O.D. Approximately the same percentage removals of suspended solids are obtained when tan liquors are excluded as when they are treated with the rest of the wastes. Exclusion of tan liquors increases the percentage removal of B.O.D. Limited data on full scale plants in actual operation indicate that the suspended solids removals are about as high as in the experimental plants but B.O.D. results are less satisfactory in many cases.

A survey by the Massachusetts State Board of Health in 1934 of the pretreatment works at 47 tanneries in Peabody and 25 in Salem, Massachusetts, showed the weighted average removal of suspended solids to be about 41 percent in Peabody and 36 percent in Salem. The average detention period of the sedimentation tanks in Peabody was found to be 3.0 hours and in Salem 1.1 hours.

Many of the tanks were not being operated properly.

Most of the tannery waste treatment plants in the Ohio Basin provide detention periods of 24 hours or more. In Pennsylvania secondary sedimentation is usually provided in basins from which a uniform outflow rate throughout the day is maintained by means of perforated, horizontal, float-supported pipes acting as outfall weirs, discharging through swinging drawdown pipes and float controlled orifice boxes. Both continuous flow and fill and draw tanks are in common use for primary sedimentation. In the former, continuous sludge collecting mechanisms are used. In the fill and draw plants sludge collecting equipment is not provided. These plants usually include three primary tanks, one of which is always out of service for cleaning.

Where primary treatment is sufficient, it is often feasible to segregate the stronger wastes and treat them, discharging the wastes containing only small amounts of suspended solids without treatment. Segregation of the spent tan liquors and soda bleaches is common practice where color reduction is desired. The remaining wastes are usually settled. The tan liquors and soda bleaches are lagooned and discharged to the stream during periods of high flow.

Because of the great differences in the individual components of tannery wastes, it is usually desirable, though not always practicable, to mix the wastes in a definite order rather than allowing them to mix in a haphazard manner as discharged. Considerable study was given this matter by Howalt and Cavett in treating the combined wastes from the Instanter tannery and by Maskey in treating only beam house wastes. It is difficult to generalize on the results of these studies because of differences in processes at various tanneries but in the design of treatment works it is desirable to consider the possibilities of controlled mixing of the wastes. Such treatment may require considerable changing of plant sewers, the construction of sumps or holding tanks, multiple pumping, and may complicate operation.

Chemical Precipitation

Coagulation takes place to a considerable degree upon mixing of the plant wastes. A number of experiments have been made to determine a method of increasing the efficiency of treatment by the addition of chemicals. In many of these experiments the use of an acid (CO_2, H_2SO_4, SO_2) has been used to reduce the pH of the wastes to below 7.0 (usually 5.5-6.5) followed by the use of one of the common coagulants. Flue gas and lime were used by Riffenburg and Allison. Sulfuric acid or sulfur dioxide and either aluminum sulfate or lime or both were used by Howalt and Cavett. Flue gas and ferric chloride were used by Maskey. Sarber found that sulfuric acid gave approximately the same results as flue gas when used with ferric chloride. The use of various coagulants without acidification has also been studied.

In most instances the added efficiency due to chemical treatment has been found to be too small to justify the use of chemicals as a general practice. The principal use that has been made of chemical treatment is to reduce the caustic alkalinity of the wastes in order to prevent the deposition of calcium carbonate in sewers. Clark's experiments led to the adoption of the flue gas for reducing the caustic alkalinity of tannery wastes which were causing trouble by clogging the sewers at Peabody, Massachusetts.

Secondary Treatment

Further treatment by the various biological treatment devices in common use has been successful in experimental plants but relatively little has been done in actual practice. Fales states that intermittent sand filters have been successfully operated at several Massachusetts tanneries. At Gloversville, N.Y., where wastes from about 25 tanneries are treated with the municipal sewage from a town of 23,000 people, a plant with trickling filters followed by intermittent sand filters has been in successful operation for more than 30 years. At Elmshorn in northern Germany an activated sludge plant treats a mixture of about one-half tannery waste and one-half domestic sewage, removing about 80 percent of the B.O.D. of the combined wastes.

In general, experimental work has shown that intermittent filters with either sand or cinder filter media are the most efficient devices for color removal as well as for reduction in B.O.D. Trickling filters are somewhat less efficient for removal of B.O.D. and much less efficient in removing color. Activated sludge is more easily upset by occasional overloads or by causticity of the applied waste than either trickling filters or intermittent filters. No data are available on the suitability of recirculating filters for treating tannery wastes.

Extensive experiments in Pennsylvania and Michigan indicated that mixture of the wastes, sedimentation and filtration using trickling filters would reduce the suspended solids content by about 85-95 percent, the B.O.D. by 65-75 percent and the color by 15-70 percent. Although comparable data on the efficiency of intermittent filters are not available, the results of the Chicago tannery testing station indicated that intermittent filters were more efficient than trickling filters or activated sludge in removing both B.O.D. and color.

It is important that the wastes as applied to the filter not contain caustic alkalinity. Seeding of the filter with the proper organisms is necessary. At the Chicago tannery testing station it was found that the filter could be started by treating only the soak liquors from the tannery. Sarber developed an efficient growth on a trickling filter treating beam house wastes by seeding it with pure cultures of proteolytic organisms isolated from soak liquors, sewage, manure, etc.

Sludge Disposal

One of the major problems in tannery waste treatment is sludge disposal. Approximately 7 to 10 percent of the total waste volume must be disposed of as sludge. Underdrained sludge drying beds do not appear to be appreciably more efficient than those not underdrained. Pennsylvania recommends equipping the beds with skimming pipes to remove the clean supernatant liquor and rain water. Lagoons are used extensively where land is available. The sludge has some value as fertilizer and is valuable on acid soils because of its high lime content. Vacuum filters and centrifuges have been used to some extent but are not wholly satisfactory.

Size of Units

Primary and secondary sedimentation tanks are usually designed to provide 24 to 36 hours detention. They should be equipped with paddles for mixing during the period when wastes are entering the tank. Pennsylvania and Michigan recommend operating rates of from 1.25 to 1.50 m.g.d. per acre for trickling filters. Lagoons for storage of spent tan liquors and soda bleaches should provide about 325 gallons capacity per pound of hide per day. Sludge beds should provide about one square foot of area per pound of hide per day.

Suggested designs of waste treatment works are included in the Pennsylvania Department of Health bulletin "Treatment of Tannery Wastes" and in Michigan Engineering Experiment Section Bulletin No. 82.

Costs

The most complete data on the cost of tannery waste treatment are contained in the above mentioned Pennsylvania bulletin. They are based on the experience obtained in designing, building, and operating the full scale experimental plant at Emporium. The tannery handles 13,500 pounds of hide per day. Estimated capital costs were:

Mixing and sedimentation 24-hr. discharge	$22,500
For filtration and resetting add.	7,000

Annual Operating Costs (307 operating days):

Mixing and sedimentation 24-hr. discharge	$2,300
With chemical precipitation	6,700
For primary filtration add.	1,500
For Secondary filtration add.	1,000

Bibliography

(1) R. S. Bonsib, What Tanners Should Know about Sewage Disposal. Tanners Council of America, 1920.

(2) Sanitary District of Chicago, Results of Sampling and Gaging Studies of Various Industrial Wastes (unpublished)

(3) H. W. Clark, Carbonation of Industrial Waste to Prevent Clogging. Water Works and Sewerage 79,52 (1932)

(4) E. F. Eldridge, Report on Sanitary Engineering Projects for 1935. Michigan Engineering Experiment Station Bulletin No. 67 (March, 1936).

(5) E. F. Eldridge, Industrial Waste Treatment Processes and Plant Design. Michigan Engineering Experiment Station Bulletin No. 82 (Sept., 1938)

(6) E. F. Eldridge, Report on Sanitary Engineering Projects, 1938. Michigan Engineering Experiment Station Bulletin No. 83. (November, 1938)

(7) E. F. Eldridge, correspondence.

(8) Almon L. Fales, Industrial Waste Disposal (Discussion) Proceedings of American Society of Civil Engineers 54, 312 (Jan. 1928).

(9) H. Furkert, Mechanical clarification and biological purification of Elmshorn sewage, a major portion of which is tannery waste. Tech. Gemeindeblatt, 39,285 (1936), 40,11 (1937) Chemical Abstracts 31,5076 (1937).

(10) J. W. Harnley, F. B. Wagner and H. G. Swope. Treatment of Tannery Wastes at the Griess-Pfleger Tannery, Waukegan, Ill. Sewage Works Journal, 12,771 (July,1940).

(11) H. B. Hommon, Studies on the Treatment and Disposal of Industrial Wastes. U. S. Public Health Service, Public Health Bulletin No. 100, (1919).

(12) Wilhelm Howalt and Edwin S. Cavett, Studies of Tannery Waste Disposal. Proceedings, American Society of Civil Engineers 53, 1675 (Sept. 1927).

Bibliography

(13) G. E. Hubbell, Tannery Waste Disposal at Rockford, Mich. Water Works and Sewerage, 82, 331 (1935).

(14) D. F. Maskey, A Study of Tannery Waste Disposal I., Heavy Leather Beam House Effluents. Journal American Leather Chemists Association 36, 121 (March, 1941).

(15) Commonwealth of Massachusetts, Report of the Joint Board Established for an Investigation of the Sewage Problem of the South Essex Sewerage District. House No. 1250 (Nov. 1934).

(16) F. B. Milligan, Tannery Waste Treatment in Pennsylvania. American City, Feb., 1938 p. 50.

(17) F. B. Milligan correspondence.

(18) F. W. Mohlman, Treatment of Packing House, Tannery and Corn Products Wastes. Industrial and Engineering Chemistry, 18, 1076 (1926).

(19) Oberlander, T., Treatment of Tannery Wastes, Journal American Leather Chemists Association, 27,393 (1932).

(20) Fred O'Flaherty, Correspondence.

(21) Ohio River Pollution Survey files.

(22) J. S. Parker, Combination Plant Treats Sewage and Tannery Wastes at Middlesborough, Ky. Water Works and Sewerage, 88, 109 (March, 1941).

(23) Pennsylvania Department of Health, Treatment of Tannery Wastes. (1930).

(24) H. B. Riffenburg and W. W. Allison, Treatment of Tannery Wastes with Flue Gas and Lime. Industrial and Engineering Chemistry, 33,801 (1941).

(25) Raymond W. Sarber, Tannery Waste Disposal II. The Use of the Trickling Filter on Effluent of a Sole Leather Beam House. Journal American Leather Chemists Association 36, 463, (August, 1941).

(26) K. S. Watson, Correspondence.

(27) West Virginia State Water Commission. First Annual Report 1929-30.

TANNERY WASTES

Plant Hyde Tanning Co State Ky. Ref.No. RH - 165

City Black Springs County Yancey Main Watershed Roaring River

Address 418 Limestone St. Sub-watershed Hemlock Cr.

Informant C.G. Hyde Title President Principal Product Sole Leather

Plant Operation:	Hours per Week	Days per Year	Plant Employees
Average	48	300	100
Maximum			

Seasonal variation Slight variation

WATER SUPPLY:-	Source	Av. g. p. d.	Max. g. p. d.	Treatment
Drinking	Municipal Supply	140,000		Boiler only
Industrial				Zeolite Softened
Cooling				

RAW MATERIALS:- Raw hides 15,000 lb. salted Cow and Steer hides (average 52 lb. per hide)

Chemicals:- Lime 1,500 lb. per day Sulphuric Acid 300 lb. per day

~~Chrome~~ Sodium Sulfide 40 lb. per day Dye

Other Soda ash 120 lb. per day

PRODUCTS:- Sole Leather 10,500 lb. per day

WASTES:- Quantity 115,000 g.p.d. How estimated Measurements at outfall, Vat capacities

~~Washings~~ Soaks 12,000 g.p.d. Lime 6,000 g.p.d.

Acid bleach 2,000 g.p.d. acid water 2,000 g.p.d. ~~Chrome~~ Soda bleach 2,000 g.p.d.

Dye Other Hot water 7,500 g.p.d.

Possible spills

~~Grease trap~~ Other wastes 131,500 by difference

Analyses:- Number None Date By whom

Appearance Black

OUTLET:- Where to Treatment plant, private outfall through ditch to Hemlock Cr.

Description:	Size and shape	Material	Location	Elevation
1.				
2.				
3.				

Gaging possibilities Good at raw waste sump or at outlet

Conditions below outlet: Color Black

Turbidity slight Deposits None visible

SANITARY SEWAGE: Disposal Municipal Sewer Persons tributary 110

REMARKS Spent tan liquors evaporated (7,500 g.p.d.) Residue sold as boiler compound.
See attached sheet for data on treatment plant for other wastes.

Survey by W Wimple Date 8-24-1939

OHIO RIVER POLLUTION SURVEY - U.S.P.H.S. - CINCINNATI, OHIO

INDUSTRIAL WASTES v (Not an actual tannery)

River Mileage Index No. RH-165

Type of Plant Vegetable Tannery **State** Kentucky

Name of Plant Hyde Tanning Company

Municipality Black Springs **Main Watershed** Roaring River

County Yancey **Subwatershed** Hemlock Creek

Address 418 Limestone St.

Source of Information C. G. Hyde, company president

Plant Operation:-

48 hours per week, 300 days per year
100 employees ave.

Seasonal Variation:- Slight variation

(Survey report continued on next page)

Survey by W. Wimple **Date** 8-24-39

Sewered Population Equivalent Computation:-

Factors used per 100 pounds of hide per day

B.O.D. 14 Suspended solids 16

Sewered population equivalent* based on B.O.D. 2,100

Sewered population equivalent* based on suspended solids 2,400

Remarks: Allow 70% reduction in B.O.D. for evaporation of spent tan liquors and sedimentation. Allow 80% reduction in suspended solids for treatment.

Computation by: C. W. Holmes Date 9-12-39 Cincinnati office

Note: This computation is of a preliminary nature and may be subject to revision as more information on this plant or the factors used becomes available.
*Rounded to nearest 100

Hyde Tanning Co. RH 165

Water Supply - All water from municipal supply. Average 140,000 g.p.d. Boiler water zeolite softened. Other water untreated.

Raw Materials - Average quantities per day:

Salted cow and steer hides (ave.52#)	15,000 lb.
Lime	1,500 lb.
Sodium sulfide	40 lb.
Soda Ash	120 lb.
Sulfuric Acid	300 lb.

Products - Sole Leather 10,500 lb. per day.

Wastes - 115,000 g.p.d. (estimated by treatment plant operator from measurements at outfall and by plant engineer from plant operations)

Soaks	12,000 g.p.d.
Hot water	7,500 "
Limes	6,000 "
Acid Bleach	2,000 "
Soda Bleach	2,000 "
Acid Water	2,000 "
Other wastes (by difference)	83,500 "

7,500 g.p.d. spent tan liquor evaporated. Residue sold for boiler compound.

Analyses - None

Outlet - To treatment plant, outfall direct to Hemlock Creek through ditch.

Plant units include: (a) sump for raw wastes with automatic float controlled pump; (b) 45' diameter Dorr clarifier, 120,000 gal. capacity; (c) earth equalizing basin, 120,000 gallons capacity, equipped with horizontal, perforated, float supported swinging collector pipe discharging to (d) float controlled orifice box which maintains a uniform outflow rate to Hemlock Creek.

Sludge from Dorr clarifier pumped to lagoon in low area adjacent to plant. Supernatent collected by ditches and returned to clarifier. Equalizing basin drained and cleaned on alternate Sundays. Sludge to lagoon. Farmers haul away part of sludge.

Gaging Possibilities - Good at either sump or orifice box.

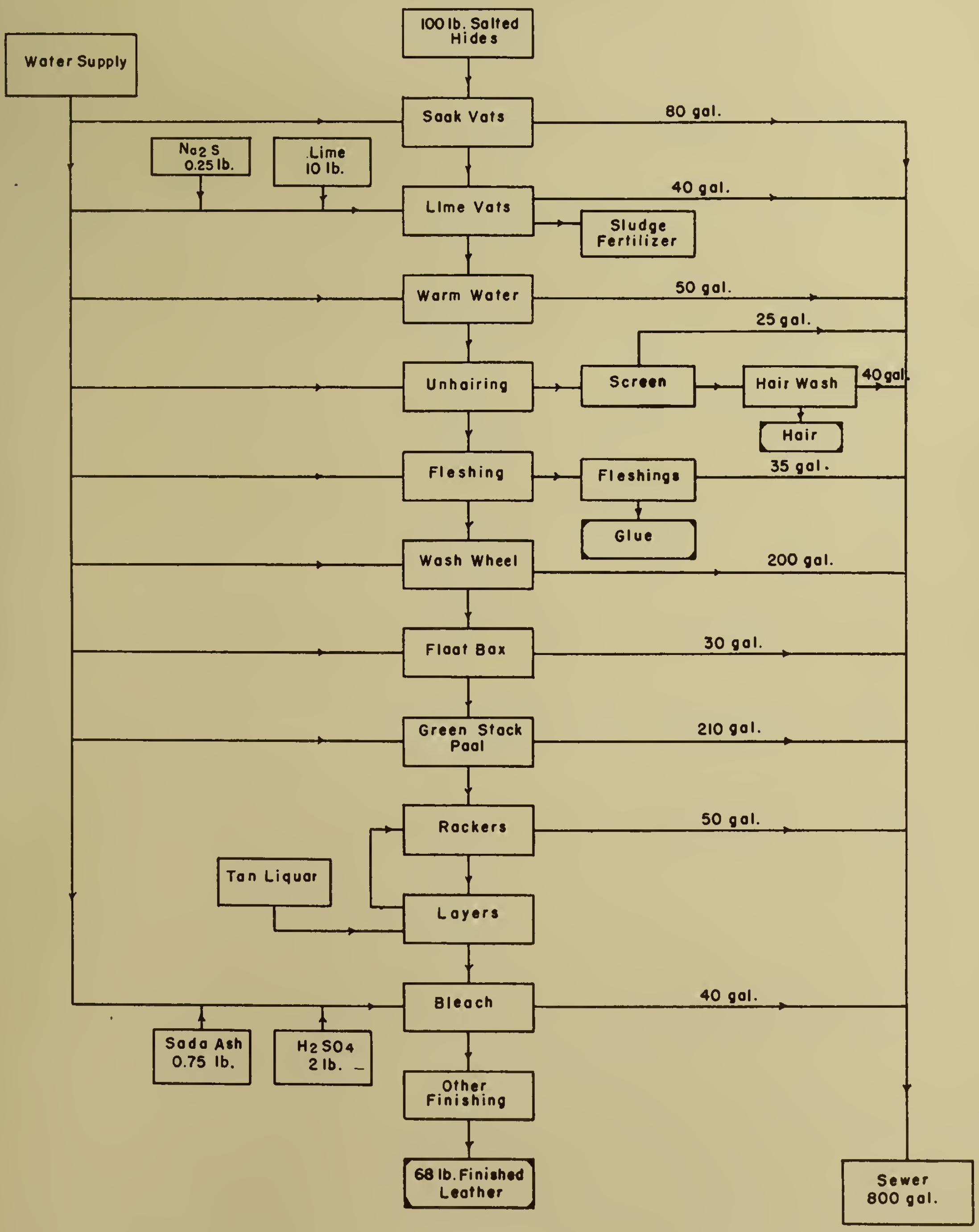
Conditions below Outlet - Stream low at time of visit. Color, black. No sludge deposits apparent.

Remarks - Numerous complaints have been made about color of stream in the past. Color was apparent as far downstream as mouth of Hemlock Creek 25 miles away. Since installation of evaporators for spent tan liquor color is apparent for only about three miles downstream. No complaints recently.

FLOW DIAGRAM

TANNERY

VEGETABLE TAN PROCESS



OHIO RIVER POLLUTION SURVEY
U. S. PUBLIC HEALTH SERVICE
1942

UNIVERSITY OF ILLINOIS-URBANA
3 0112 109115003